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Optimization and Quality Assessment of Fertilizers Based on Resource Recovery Technologies

Master's thesis submitted for examination for the degree of Master of Science in Technology

In Espoo 23.9.2019
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Tiivistelmä

Tämän diplomityön tavoitteena oli tutkia NPHarvest-tuotteiden laatua sekä ravinteiden talteenottoon perustuvien lannoitteiden optimointimahdollisuuksia ja tulevaisuuden vaatimuksia imagolle ja haitta-aineille. Tutkimus koostuu kirjallisuustutkimuksesta ja kokeellisesta osuudesta.

Optimaalisen tuotteen ravinnepitoisuus olisi korkea, haitallisten aineiden ja mikrobien pitoisuus matala sekä lannoittavat vaikutukset hyvät. Nykyinen Suomen lannoitelainsäädäntö rajoittaa ainoastaan haitallisten metallien ja kahden indikaattoribakteerin esiintymistä lannoitetuotteissa. Lainsäädäntö kuitenkin tiukentunee haitta-aineiden osalta. Vaikka kiertotalousajattelua tuetaankin laajasti, ravinteiden talteenottoon perustuvia lannoitetuotteita kohtaan voi olla myös negatiivista suhtautumista. Pidemmälle käsiteltyjen ravinteiden talteenottoon perustuvien lannoitetuotteiden imagoa pitäisi vielä tutkia.

Tämän diplomityön kokeellisessa osuudessa käytettiin NPHarvest-pilottilaitteistoa Viikinmäen jätevedenpuhdistamolla. Prosessin esikäsittely tuottaa lietettä ja kalvoreaktori ammoniumsulfaattia. Lietteen hygienisointiin ja kuivaamiseen testattiin kolmea eri menetelmää. Tämän jälkeen tuotteiden laatua tutkittiin ja niille tehtiin kasvukokeita.

Tehtyjen analyysien perusteella lietteen hygienisointia tulisi kehittää. Tuotteissa oli matalat pitoisuudet orgaanisia haitta-aineita ja haitallisia metalleja. Lietetuotteet voisivat toimia paremmin kalkin ja muiden sivuravinteiden kuin pääravinteiden lähteinä. Ammoniumsulfaattiliuoksen ominaisuudet todennäköisesti paranevat, kun liuos on täysin saturoitunutta ja käytetty happo vahvempaa.

Avainsanat lannoite, ravinne, talteenotto, rejektivesi, jätevesi, fosfori, typpi

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Abstract

The goal of this master's thesis was to research the quality of the NPHarvest products as well as the optimization possibilities and the future demands for public image and pollutant removal of resource recovery fertilizers. This study consists of a literary review and an experimental part.

An optimal product would have a high nutrient content, a low content of harmful substances and microorganisms and good fertilizer qualities. The current Finnish legislation restricts only harmful metals and two indicator bacteria in fertilizers. However, the pollutant legislation is likely to become stricter. Even though circular economy is widely promoted, there can be negative attitudes towards resource recovery-based fertilizers. The public image of further treated resource recovery-based fertilizers should still be studied.

The experimental part of this thesis was performed in Viikinmäki wastewater treatment plant with the NPHarvest pilot reactor. The pretreatment of the process produces sludge and the membrane reactor produces ammonium sulfate. The hygienization and dewatering of the sludge was tested with three different methods. After this, the quality of the product was examined and growth tests were performed.

Based on the performed tests, the hygienization process should be reconsidered. Organic pollutants and harmful metals were mostly present in low concentrations in the products. The sludge products could work better as a source of calcium and other secondary nutrients than as primary nutrient sources. The properties of the ammonium sulfate solution are likely to improve when fully saturating the solution and using a stronger acid.

Keywords fertilizer, resource, nutrient, recovery, reject water, wastewater, phosphorus, nitrogen

Foreword

This master's thesis was completed as a part of the NPHarvest project in Aalto University. The research project studies nutrient recovery from liquid waste streams. This master's thesis concentrates especially on the quality of the end products, as this has not been studied profoundly in the earlier parts of the project. The project receives funding from the RAKI2 -program by the Ministry of the Environment.

This thesis was supervised by Professor Anna Mikola and advised by Maria Valtari. They provided help and support, which was indispensable for finishing the project, and for that I am very grateful. I would also like to extend my gratitude to all the other staff members of the Water Building involved in the project: Heikki Särkkä, Antti Louhio, Juho Kaljunen, Surendra Pradhan and Marina Sushko. Special thanks to Aino Peltola for all the emotional and laboratory support she provided. I would also like to thank all the members of the steering group of the NPHarvest project for their collaboration, especially Anne-Mari Aurola (Nordkalk), Titta Berlin (Finnish Food Authority) and the Biolan representatives: Hannamaija Fontell, Suvi Lahti and Tuomas Pelto-Huikko. Many thanks to Leena Tanttu and Tiina Huuhilo from Outotec for their invaluable filtering help.

Last but not least, I would like to thank the most important people in my life: my family and my husband. My deepest gratitude to my mother for her shared expertise on filtering, my whole family for their love, support and sarcastic comments, and Mikko, for always being there – even when the physical distance between us was over 7 000 km. Thank you, kiitos, gracias.

Espoo 23.9.2019

Irene Konola

Contents

Markings and abbreviations

6:2 FTS	1H,1H,2H,2H-perfluorooctane sulfonate
As	Arsenic
B	Boron
Ca	Calcium
$Ca(OH)_2$	Calcium hydroxide
Cd	Cadmium
CFU	Colony forming unit
Co	Cobalt
Cr	Chromium
Cu	Copper
EU	European Union
Fe	Iron
GC	Genome copy
Hg	Mercury
K	Potassium
LKD	Lime kiln dust
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
Na	Sodium
NH_4-N	Ammonium nitrogen
Ni	Nickel
NO_x-N	Nitrite and nitrate nitrogen
P	Phosphorus
PAH	Polycyclic aromatic hydrocarbon
PFC	Perfluorinated compound
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
Pb	Lead
PO_4-P	Phosphate phosphorus
S	Sulfur
Se	Selenium
TOC	Total organic carbon
TS	Total solids
Zn	Zinc

1 Introduction

Phosphorus and nitrogen are two main components of fertilizers. Nowadays, nitrogen is produced with the energy intensive Haber-Bosch process and currently known mineral phosphorus sources will be depleted eventually, possibly only in a few decades, and the price of mineral phosphorus has increased (Neset and Cordell 2012, Ylivainio and Kapuinen 2012, Puchongkawarin et al. 2015). Meanwhile there are many waste streams rich in nitrogen and phosphorus that could be used to produce part of the needed fertilizers.

One of these sources is reject water, which is the water coming out of dewatering sewage sludge or digestates through, for example, centrifuges. Reject waters are high in nutrients and impact the treatment processes due to internal cycles in the treatment plants. The pilot tests of this thesis have been done on reject water from the biggest wastewater treatment plant of Finland, Viikinmäki in Helsinki.

A research group of Aalto University has developed a process to harvest nutrients from liquid waste streams. The process is called NPHarvest and it is currently in piloting phase. The NPHarvest process has been used in the experimental part of this thesis. It consists of a pretreatment unit, which produces a phosphorus and calcium rich sludge via ballasted sedimentation and a membrane reactor, which captures ammonium in acid. The basic process parts can be seen in Figure 1 and a more in-depth description of the process can be read in earlier reports of the NPHarvest project (Kaljunen 2018). The NPHarvest products are presumably rich in nutrients and their fertilizer properties are examined in this thesis.

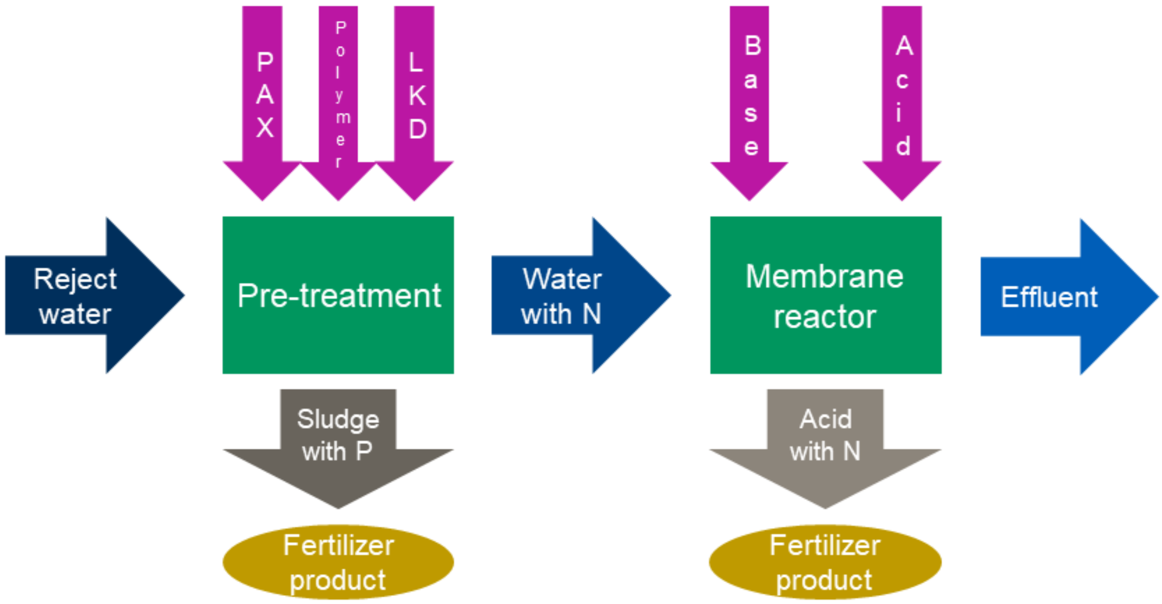

Figure 1 Simplified diagram of the NPHarvest process

This thesis aims to answer to the following questions:

- What are the NPHarvest products' qualities as fertilizers, hygienically and regarding harmful substances (both heavy metals and organic pollutants)?
- How should resource recovery fertilizer products be optimized?

- What are the future demands for resource recovery-based fertilizers in terms of image and pollutant legislation?

This master's thesis continues the work done by the NPHarvest research team, focusing especially on the NPHarvest products. The experimental part of the thesis concentrates on applying the NPHarvest method to Viikinmäki reject water. Other liquid waste streams, such as biogas plant reject water, are evaluated in other parts of the NPHarvest project and will not be included in this thesis. In addition, the technical solutions and treatment methods are further examined in previous reports of the NPHarvest project. This thesis does not include a cost estimation for the products as previous reports of the NPHarvest project have already covered most of it. (Kaljunen 2018, Sah 2019) Previous reports have also analyzed the sustainability aspects of harvesting nutrients from waste streams (Kaljunen 2018, Pihl 2017), so that is not included in this thesis either.

2 Literary review

2.1 Fertilizer legislation

2.1.1 European Union legislation

Current regulation

The current European Union fertilizer legislation is from the year 2003. It brings together all the EU fertilizer legislation to one regulation. In 2016, the preparation for a simpler fertilizer legislation was started. (Publications Office of the European Union 2016) A new regulation has just been published in the spring of 2019 and will start applying in three years (Council of the European Union 2019a).

The current EU legislation on fertilizers from 2003 affects only mineral fertilizers. All other types of fertilizers are regulated with national legislation in each member country. The regulation sets limits for the nutrient content and safety of the fertilizers. (Publications Office of the European Union 2016)

The regulation distinguishes three different kinds of nutrients. Primary nutrients are nitrogen, phosphorus and potassium. Secondary nutrients include calcium, magnesium, sodium and sulfur. Micronutrients affect plant growth in smaller quantities and they are a variety of metals. (Publications Office of the European Union 2016)

New regulation

In contrast to the current regulation, the new EU regulation aims to consider organic and recycled fertilizers in addition to the mineral or chemically produced inorganic fertilizers. This could help encouraging to the use of fertilizers that could also promote circular economy. Even though the aim is to include more fertilizer products in the regulation, products outside the regulation are also allowed, as long as they are in accordance to the national legislation of the place of production or use. (Council of the European Union 2019b)

The new regulation also intends to take into consideration the products composed of a mix of fertilizer products. The new regulation has different product function categories that have different requirements, for example inorganic fertilizers and liming materials have their own product function categories. The products can be a mix of these function categories. It also has different component material categories, which also have varying requirements regarding the process and control mechanisms. The products can have different component materials, which can be from different component material categories, for example compost (Component Material Category 3) and food industry by-products (Component Material Category 6). (Council of the European Union 2019b)

The current EU legislation has been criticized of not being very supportive for recycled phosphorus fertilizers. It has been stated that the legislation should be harmonized and the Fertilizer Regulation revised to support more sustainable phosphorus producing practices. (Hukari et al. 2016) Indeed, the new regulation identifies for example struvite as a product with a certain demand for fertilizer use (Council of the European Union 2019b). Struvite is a substance that contains magnesium, ammonium and phosphate and is formed in wastewater treatment plants and can be collected for more sustainable fertilizer production (Forrest et al. 2008). There is also a draft for the safe recovery of precipitated phosphate salts (such as struvite) to be included in the European fertilizer legislation. (Subgroup of the Commission expert group on Recovery Rules for Fertilising Products 2018)

Considering resource recovery-based fertilizers, the new regulation also identifies the need for requirements for the input waste, treatment processes and end products. It also indicates that these products should not be seen as waste. The new regulation states: "To ensure legal certainty, take advantage of technical developments, and further stimulate the incentive among producers to make more use of valuable waste streams, the scientific analyses and the setting of recovery requirements at Union level for such products should start immediately after the entry into force of this Regulation." (Council of the European Union 2019b)

2.1.2 Finnish legislation

General requirements

The national legislation will be updated in the near future, starting in the beginning of 2020 (Berlin 2019). At the moment, the most important piece of Finnish legislation regarding fertilizers is the Fertilizer Product Act (539/2006). It aims to ensure the safety and fitness of fertilizer products used and produced in Finland. It states that fertilizers must fill the requirements set in various pieces of legislation and there should not be harmful substances in amounts that put safety or health at risk when the products are used according to their instructions for use. The quality of the products should also be homogenous. (Fertiliser Product Act 539/2006)

Before starting as an operator in the manufacture, processing or storing of fertilizer products, one has to be approved by the Finnish Food Safety Authority. After this, when the activities are running, the manufacturers and other operators involved in the processing of fertilizer products must keep an updated data set of their activities to be used by the controlling authorities. All the fertilizer products should be regularly controlled by control authorities. In addition, the operators in the fertilizer product field must perform self-supervision on the critical steps of manufacturing or processing the products and self-supervision is reported annually to the Finnish Food Safety Authority. (Fertiliser Product Act 539/2006) The requirements regarding the supervision, control and other activities of the operators are issued in more detail in the Decree of the Ministry of Agriculture and Forestry (11/2012).

Type designations

For a fertilizer product to be legally in the markets, it must have an approved type designation (Fertiliser Product Act 539/2006). The type designations and the restrictions related to them are presented in the Decree of the Ministry of Agriculture and Forestry (24/11). There are five different types of fertilizer products: fertilizers (inorganic or organic), liming materials, soil conditioners, microbe products and growing media (Decree of the Ministry of Agriculture and Forestry 24/11). All the fertilizer products with a type designation must affect the growth of plants by providing sufficient nutrients or improving growing conditions (Fertiliser Product Act 539/2006).

Regarding the inorganic fertilizers, the Decree of the Ministry of Agriculture and Forestry 24/11 states that they cannot contain organic matter from animals or plants. The TOC content cannot be over 1% of the solids of the fertilizer. There are several type designations for inorganic fertilizers for a variety of products. The type designation 1A1 is for the inorganic primary nutrient fertilizers with one nutrient. In these fertilizers, the content of that primary nutrient must be over 3%. Organic fertilizers come from animal, plant and/or microbe sources. There are also different type designations for the organic fertilizers corresponding to different sources of the matter (animal/non-animal/microbe) and other fertilizer characteristics. (Decree of the Ministry of Agriculture and Forestry 24/11)

The second group of fertilizer products are liming materials. Their main function is to improve the soil qualities and nutrient availability by adjusting the pH of the soil and water. The materials can also include other nutrients. The calcium and/or magnesium of the products should be mainly oxides, hydroxides, carbonates or silicates. (Decree of the Ministry of Agriculture and Forestry 24/11)

Soil conditioners are defined as substances that improve the quality of the soil physically, chemically or biologically. In addition, soil conditioners can contain high concentrations of nutrients. Soil conditioners include turfs among others. (Decree of the Ministry of Agriculture and Forestry 24/11) In the current legislation, fertilizer products that contain organic material and come from human sources (like sewage sludge), are soil conditioners (Berlin 2019, Peltonen et al. 2013).

Microbe products contain bacteria or fungal populations isolated from the nature. Growing media can be turfs, moss or other media meant for growing plants. Growing media can be mixed with other fertilizer products as well. (Decree of the Ministry of Agriculture and Forestry 24/11)

Restrictions for fertilizers

There are limits for the maximum concentrations of certain metals in the fertilizer products. In addition, there are some hygienic quality limitations. These limits are presented in Table 1. Besides these substances and microorganisms, there are several plant diseases and weeds restricted. (Decree of the Ministry of Agriculture and Forestry 24/11) Regulations on nitrate are issued in the Decree of the Council of State (931/2000).

Table 1 Legislation limits for harmful metals and hygienic quality (Decree of the Ministry of Agriculture and Forestry 24/11).

Restricted material	Legislation limit
Cd	1.5 mg/kg dry matter
As	25 mg/kg dry matter
Hg	1 mg/kg dry matter
Cr	300 mg/kg dry matter
Cu	600 mg/kg dry matter
Pb	100 mg/kg dry matter
Ni	100 mg/kg dry matter
Zn	1500 mg/kg s dry matter
Salmonella	Not detected
E. coli	1000 CFU/g

The Finnish legislation restricts the use of sewage sludge fertilizers. They can only be used for cereal and oil crops and sugar beet. It is also possible to use them on other crops that are not meant for animal or human consumption as such without cooking. If the parts of the plant that are below soil surface are consumed by humans, sewage sludge fertilizers are not allowed. The pH of the soil must be over 5.8 or 5.5 in case of lime stabilized sewage sludge. (Decree of the Ministry of Agriculture and Forestry 12/12)

2.2 Fertilizer product optimization

2.2.1 Resource recovery-based fertilizers in general

Optimization parameters

The optimization of resource-recovery based fertilizer products has several aspects that should be considered. These include costs, end product quality, sustainability of production and the rate of nutrient recovery, among others. End product quality also consists of many parts: absence of harmful substances, hygienic quality, fertilizer qualities, form of end products (what do the end users prefer?) and proportion of different nutrients. These parameters have also been used to assess nutrient recovery technologies in the study by Egle et al. (2016). This section goes through the most important optimization possibilities regarding the fertilizer use of the products.

As stated before, this thesis will not include a deep cost or sustainability analysis. Nevertheless, the use of some nutrient recovery-based fertilizers have resulted in lower costs and in environmental benefits for the farmers, in comparison to the conventional chemical fertilizers (Vaneeckhaute 2015). As for the treatment plants, some nutrient recovery technologies, such as ion exchange, can require large modifications to traditional wastewater treatment plants. Others, especially the more conventional nutrient recovery applications, are additions to already existing plants and streams inside the plants – most importantly waste sludge. (Puchongkawarin et al. 2015) Using nutrient recovery technologies can decrease the effect of nutrient rich streams inside the treatment plants and provide materials to, for example, agricultural use.

Fertilizer user groups

When considering the optimization of resource recovery fertilizer products, the potential users should be considered. Two separate user groups can be identified: professional farmers and domestic gardeners. For professional farmers, the use of sewage sludge-based fertilizers has been prohibited by some grain buyers in Finland (Fazer Mills 2018, Hankkija Oy 2019, Raisio Group n.d., Viking Malt Oy 2018).

On the other hand, the domestic gardeners do not necessarily use fertilizers at all, or do not use them optimally (Dewaelheyns et al. 2013). A study performed in Germany provided information about private gardeners' views on fertilizer properties. The study was about biogas plant digestate but the results can be used to reflect other resource recovery-based fertilizers, as well. The properties that German domestic gardeners considered for the fertilizer products they used were, for example, the form of the fertilizer, the price and the brand. (Dahlin et al. 2017)

The knowledge of private gardeners regarding fertilizer products can be insufficient. The study about German gardeners stated that people did not know precisely what kind of fertilizers would be the best. Instead, the information they had about what fertilizers to use was gathered from older generations. The characteristics of fertilizers were more familiar to the respondents than soil conditioners. The lack of expertise prevented even the interested respondents of having a deep understanding of the products. (Dahlin et al. 2017)

For the form of the fertilizer, the two separate user groups – farmers and private gardeners – have to be considered. For farmers, the products have to fit the machinery used for fertilizing. According to Egle et al. (2016), the optimal grain size for fertilizers when using spreaders is 2-5 mm and the grains should be tight enough, too.

For private gardeners, personal preferences and positive associations can pay an important role when deciding the optimal form for the fertilizers. German private gardeners preferred granulate or powder in comparison to bigger forms such as pellets for biogas plant digestate products (Dahlin et al. 2017). A study revealed that there was no big difference in preference of liquid versus solid fertilizers among the domestic gardeners in Belgium that responded to a survey. (Dewaelheyns et al. 2013)

Water content and costs

Another thing to consider about the form of fertilizer products is the water content, which can be high for nutrient recovery products. Dewatering can help increasing their value. A higher solid content means a smaller volume of the product which results in less transportation costs. (Vieno et al. 2018, Bloem et al. 2017) According to the study by Bloem et al. (2017), the distances that different organic fertilizers could be transported so that the transportation would still be economical considering the provided nutrients are presented in Figure 2. For 25% dry matter content, the transportation distance of dewatered digested material would be 50 km (Bloem et al. 2017).

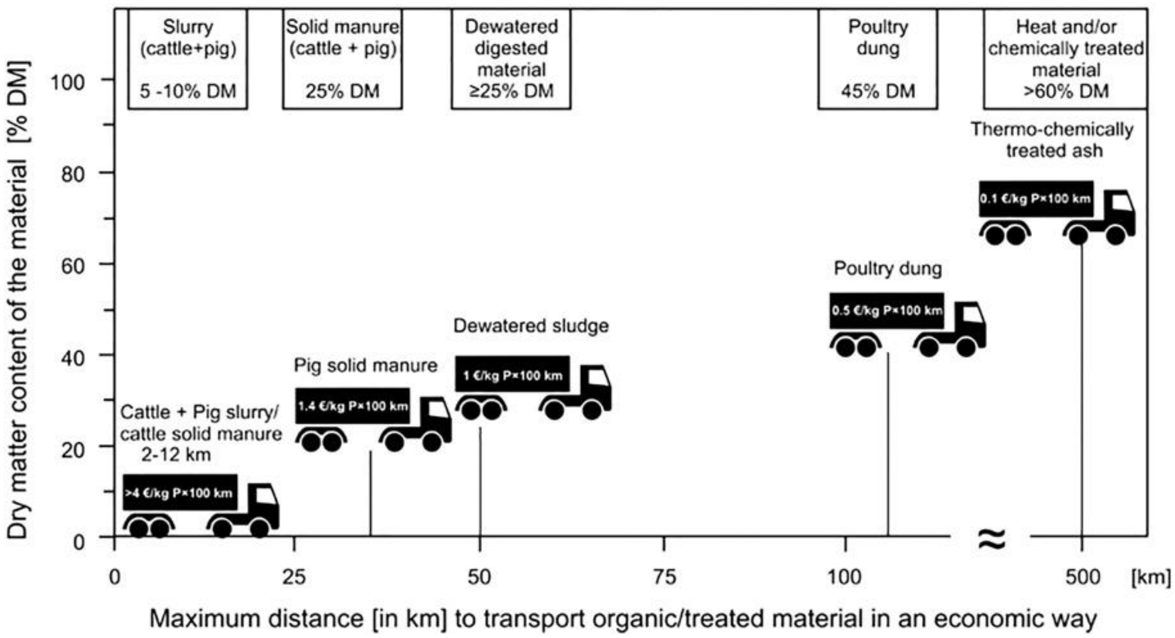

Figure 2 The distances of economic transportation of organic fertilizers from different sources and different solids content (Bloem et al. 2017).

According to Bloem et al. (2017), the reduced transportation costs do not always compensate for the costs of further treatment of the fertilizer products. Nevertheless, mechanical, chemical or thermal dewatering can affect positively also other qualities of the product, such as hygienic quality (Bloem et al. 2017). In addition, high humidity, dust or reactivity decrease the fitness for storage (Egle et al. 2016).

2.2.2 Phosphorus recovery and sewage sludge fertilizers

General

At the moment, there is much more research of sewage sludge as a fertilizer than of the further treated resource recovery fertilizer products. Because of that, this section will discuss mostly sewage sludge as a phosphorus fertilizer and what should be taken into account when optimizing soil conditioners. With the current legislation, all the sewage sludge fertilizer products in Finland are seen as soil conditioners (Peltonen et al. 2013). To decrease the potential transfer of harmful substances to the fields, sewage sludge should be further treated. It should be noted that the further treatment can also produce some inorganic phosphorus fertilizers instead of soil conditioners. (Egle et al. 2016).

The use of organic phosphorus fertilizers has increased because of the increasing price of mineral phosphorus as well as environmental concerns (Ylivainio and Kapuinen 2012). According to Bloem et al. (2017), only 0.7% of the applied fertilizer phosphorus originates from sewage sludge in Finland. 60% of the used P fertilizers are organic manure-based fertilizers. Approximately one third of the P fertilizers are from mineral sources. (Bloem et al. 2017) In another report, it was concluded that the official statistics about sludge fertilizer use in Finland do not correspond to the real situation. According to the report, about 40% of the sludge in Finland was used as a fertilizer in 2016, even though the official statistics show only a 3-5 fertilizer usage percentage. (Vilpanen and Toivikko 2017)

The properties and nutrient concentrations of fertilizers produced from sewage sludge are not constant for all the different products. This is due to, for example, different processes in the wastewater treatment plant and for nutrient recovery (Egle et al. 2016). Turf, bio-waste and other organic materials can be added to the sewage sludge-based fertilizer products. Non-organic nutrients can also be added if the nutrient concentrations of the products are not optimal. (Peltonen et al. 2013)

Phosphorus removal forms and plant-available phosphorus

In Finland, the phosphorus of wastewaters is often removed chemically by precipitating with iron or aluminium and its fertilizer qualities improve over the years. (Peltonen et al. 2013) Superphosphate is a fertilizer produced by mixing phosphate rock and an acid (Shoeld et al. 1938) and it can be used as a control test in phosphorus fertilizer growth tests. Compared to superphosphate, chemically precipitated phosphorus in sewage sludge provides a source of phosphorus for a longer time period. This indicates that chemically precipitated phosphorus could be used as a long-term phosphorus fertilizer. (Ylivainio and Kapuinen 2012)

The long-term fertilizers can be more suitable for private gardeners as they decrease the possibilities of over-fertilizing (Dahlin et al. 2017). In addition, Figure 3 shows an example of nutrient uptake for tomatoes. Nutrients are needed steadily for the whole growing time of approximately three months (Lee et al. 2017), so short-term fertilizing would probably not be enough. Nevertheless, some sources consider sewage sludge fertilizers with chemically precipitated phosphorus not very efficient fertilizers (Vaneeckhaute 2015, Plaza et al. 2007, Krogstad et al. 2005). Sludge with biologically harvested phosphorus can have similar fertilizer properties than inorganic phosphorus fertilizers (Krogstad et al. 2005).

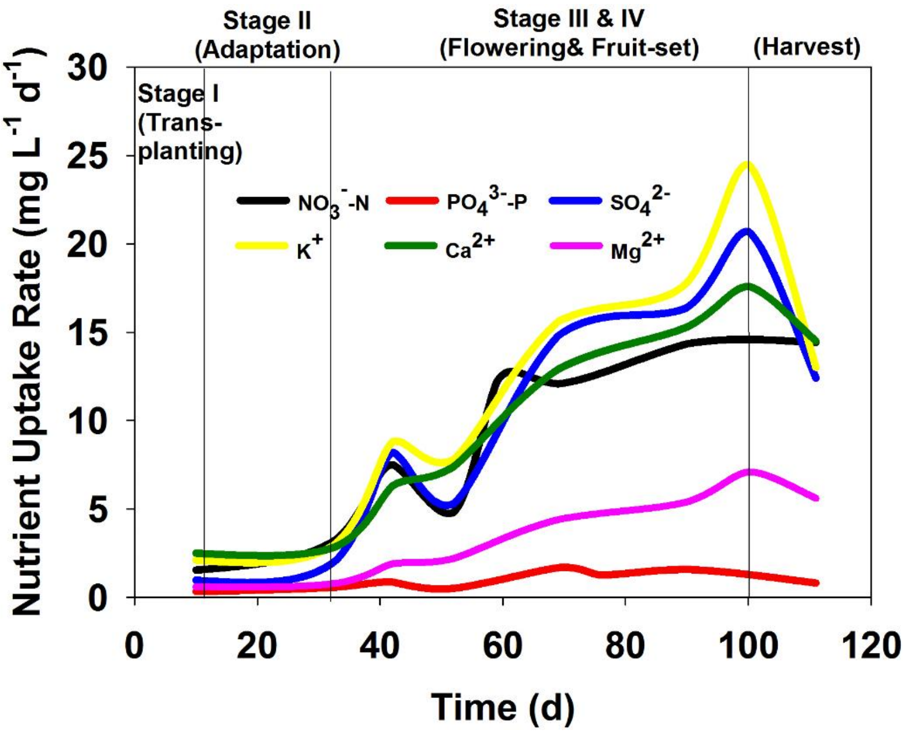

Figure 3 An example of nutrient uptake rates for tomato (Lee et al. 2017).

Another way of increasing the fertilizer properties of phosphorus recovered from organic waste streams is the addition of lime or other compounds. Lime-stabilized sludge has increased the amount of soluble phosphorus in soil compared to sludge that has not been stabilized. (Ylivainio and Kapuinen 2012) Indeed, the addition of lime to chemically precipitated phosphorus can result in equally good fertilizer effects than conventional inorganic fertilizers. As another option to increase availability, phosphorus from sewage sludge could be used together with soluble mineral phosphorus. (Krogstad et al. 2005)

Another longer-term fertilizer product that can be produced from wastewater is struvite (Puchongkawarin et al. 2015). Struvite is a structure of magnesium, ammonium and phosphate ions (Forrest et al. 2008). Wastewater-based struvite has been proved to be effective, even as effective a fertilizer as single superphosphate in growth tests (Plaza et al. 2007, Vaneeckhaute 2015). In addition, the production of struvite was assessed as the best available technology for phosphorus recovery from organic waste digestates (Vaneeckhaute 2015). In the comparison of different phosphorus recovery technologies made by Egle et al. (2016), a clearly best recovery technology could not be determined. The criteria used were the phosphorus recovery rate, absence of harmful substances, economic and environmental values, fertilizing properties, and if the product was readily applicable. None of the 19 compared technologies were the best in all of the categories, but the results rather suggested that a tradeoff between these qualities would be necessary. (Egle et al. 2016)

Safety limits of fertilizers in legislation

When using sewage sludge products instead of further treated and more pure resource recovery fertilizer products, there are some concerns about the quality. The legislation sets limits for the hygienic quality and metal concentrations of sewage sludge fertilizers (Decree of the Ministry of Agriculture and Forestry 24/11). A few decades ago, sewage sludge contained high concentrations of harmful metals, but nowadays this is not considered a problem anymore in Finland (Peltonen et al. 2013). An example of the dropped heavy metal concentrations can be seen in Figure 4.

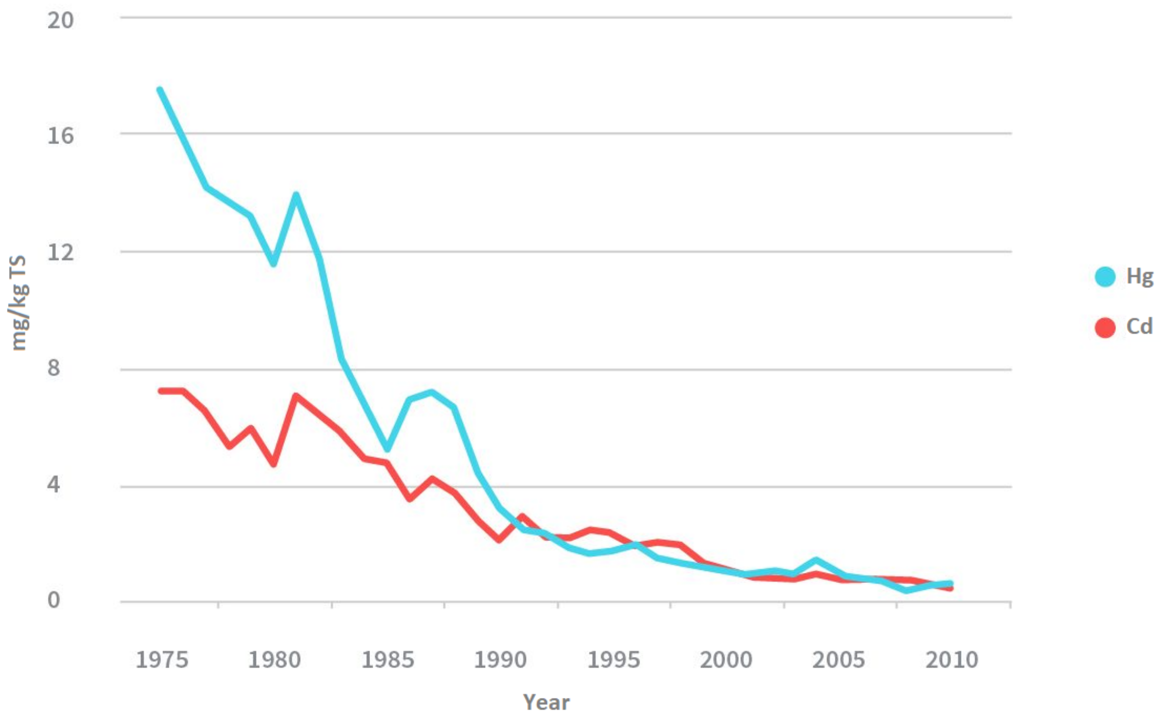

Figure 4 Mercury and cadmium concentrations in HSY sludge in 1975-2010. Modified from Finnish Water Utilities Association n.d.

Nevertheless, harmful metal concentrations can exceed the concentrations in manures and mineral phosphorus fertilizers (Bloem et al. 2017) and the limits set by the Finnish legislation as can be seen in Table 2. According to Vieno et al. (2018), the average Finnish sewage sludge soil conditioners have lower concentrations of harmful metals and the concentrations are within the limits set by legislation. Sewage sludge can be also further processed to remove heavy metals from the end products with technologies such as wet-chemical leaching and wet-oxidation (Egle et al. 2016).

*Table 2 Harmful metals in different fertilizers globally. In organic sources, the concentrations are in mg/kg of dry matter. For the mineral P fertilizer, the unit is mg/kg. Modified from Bloem et al. 2017. *Legislation limits from the Decree of the Ministry of Agriculture and Forestry 24/11.*

Element	Manures	Sewage sludge	Mineral P fertilizers	Legislation limits*
Pb	0.75-8.4	8.9-221	<0.2-13.2	100
Cd	0.08-46.1	0.34-3.4	<0.3-35.5	1.5
Cu	52-959	28-565	<2-41.8	600
Zn	81-754	140-2032	10.3-386	1500
Ni	2.9-10.4	5.5-621	7.4-48.3	100
Cr	0.2-225	8-856	16.9-196	300
Hg	0.02-0.04	0.07-2.3	<0.4	1.0
As	0.44-11.8	2.8-6.0	0.8-16.2	25

Regarding hygienic quality, there are multiple methods of producing microbiologically safe fertilizer products out of wastewater. For sludge, these methods include, among others, composting and lime stabilization. Lime stabilization can be done with calcium oxide or hydroxide. Using calcium oxide requires raising pH to over 12 and temperature to 50-70 °C for at least two hours. Calcium hydroxide does not raise the temperature in the same way, so hygienization is reached by having the pH over 12 for at least 48 hours. For the sludge of single septic tanks, two hours of pH over 12 with calcium hydroxide is enough. (Peltonen et al. 2013) Some bacteria have developed a defense mechanism against difficult conditions, forming spores. This enables them to survive extreme conditions and then developing to functional cells when the conditions are favorable again. For example Clostridia belong to this group. (Bloem et al. 2017)

New identified risks

A new concern related to sewage sludge fertilizers are the organic pollutants, for example pharmaceuticals (Peltonen et al. 2013), which are not yet restricted in legislation. For example, sewage sludge can contain high amounts of antibiotics and they can be taken up by plants. They are designed to affect different microorganisms, which makes them hazardous for the environment. (Bloem et al. 2017) In addition, bacteria populations resistant to antibiotics could be formed (Vieno 2015), but this subject should be further studied to draw conclusions.

According to Peltonen et al. (2013), studies based on current knowledge do not show considerable negative aspects on sludge fertilizer use. The report also points out that the concentrations of organic pollutants in Finnish wastewaters are below the limits that have been considered in EU legislation preparatory work (Peltonen et al. 2013). For wastewater based fertilizers, there has been preparatory work for adding limits for at least PAH_{16} substances on EU level (Subgroup of the Commission expert group on Recovery Rules for Fertilising Products 2018).

Organic matter in sludge-based fertilizers

Organic matter is known to improve soil qualities such as water retention capacity and erosion reduction (Haynes and Naidu 1998, Cooperband 2002). Organic matter can also act as a supply of carbon and energy (Cooperband 2002). Sewage sludge fertilizer products or for example different turfs have high portions of organic matter, which provides these benefits (Peltonen et al. 2013, Cooperband 2002). The positive effects of fertilizers, liming and adding organic matter to the soil conditions are shown in Figure 5. Besides improving soil properties, lime is also an important plant nutrient (Haynes and Naidu 1998).

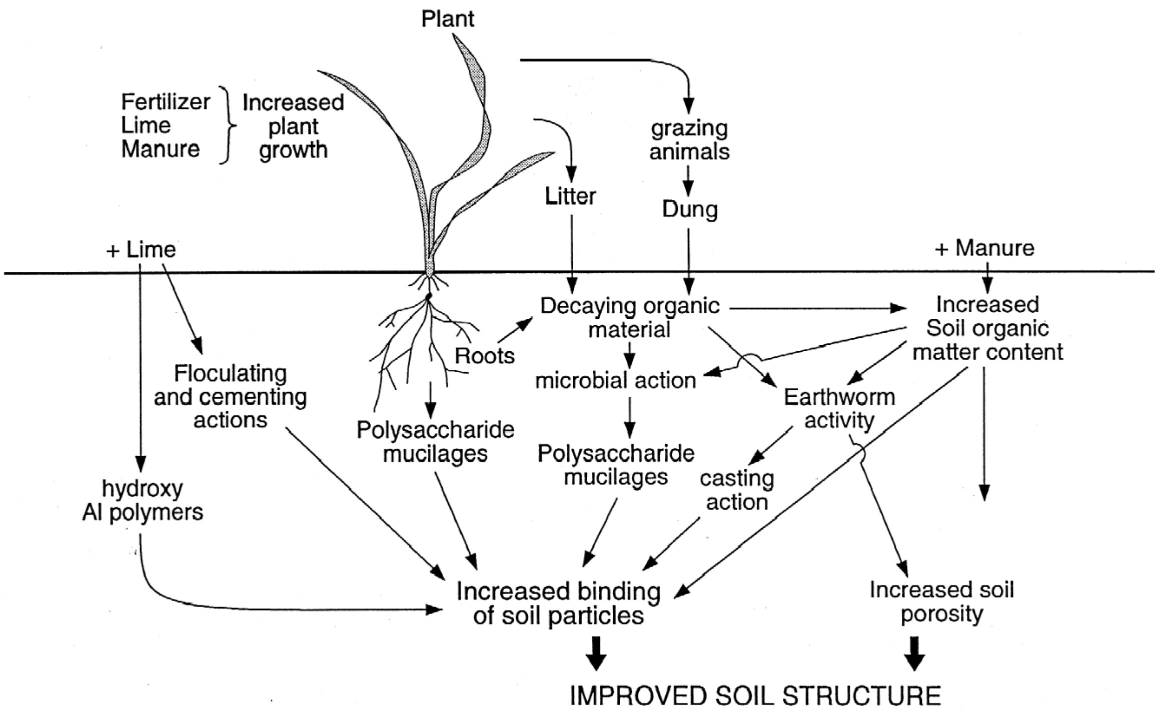

Figure 5 A conceptual model of the effects of liming, fertilizers and organic matter (in the figure, manure) on soil properties (Haynes and Naidu 1998).

On the other hand, the organic material can also mean the presence of pathogens, antibiotics and other possible risks. These risks are practically eliminated if the fertilizers are treated for example thermo-chemically so that the organic matter is almost completely destroyed. (Bloem et al. 2017) Pathogens can be removed by other hygienization methods as well.

2.2.3 Nitrogen recovery fertilizers

General

In wastewater treatment plants, nitrogen is often removed in activated sludge processes biologically to nitrogen gas (Capodaglio et al. 2015). However, there are also methods for nitrogen harvesting, which could result in more sustainable fertilizer products. In fertilizer use, soluble nitrogen, such as ammonium, has to be added to the crops yearly for the fertilizer to work properly (Peltonen et al. 2013). In Finland, almost all of the used fertilizers are either mineral or manure (Hari and Riiko 2016). The official reports might not show the real amount of fertilizer use from wastewater sources, though (Vilpanen and Toivikko 2017).

This section presents some methods for nitrogen recovery to fertilizer products. Besides those presented, producing stuvite can also be considered nitrogen harvesting (Forrest et al. 2008). Struvite contains only 6% of nitrogen by weight – compared to 12% phosphate – so it is probably not the most ideal form of nitrogen recovery (Batstone et al. 2015). The phosphorus concentration is also a limiting factor in struvite production (Xie et al. 2016).

Nitrogen harvesting technologies

According to Vaneeckhaute (2015), the best available technology in an economic, ecological and agronomic evaluation for nitrogen recovery from organic digestate is ammonium sulfate production by ammonia stripping and absorption with acidic air scrubbing. For stripping, ammonium ions are converted to ammonia gas by pH elevation to over 11 (Capodaglio et al. 2015). Raising the pH to at least 12 and higher temperatures increases the ammonia removal. An example of the effect of pH to ammonia removal over time can be seen in Figure 6. (Başakçilardan-Kabakci et al. 2007)

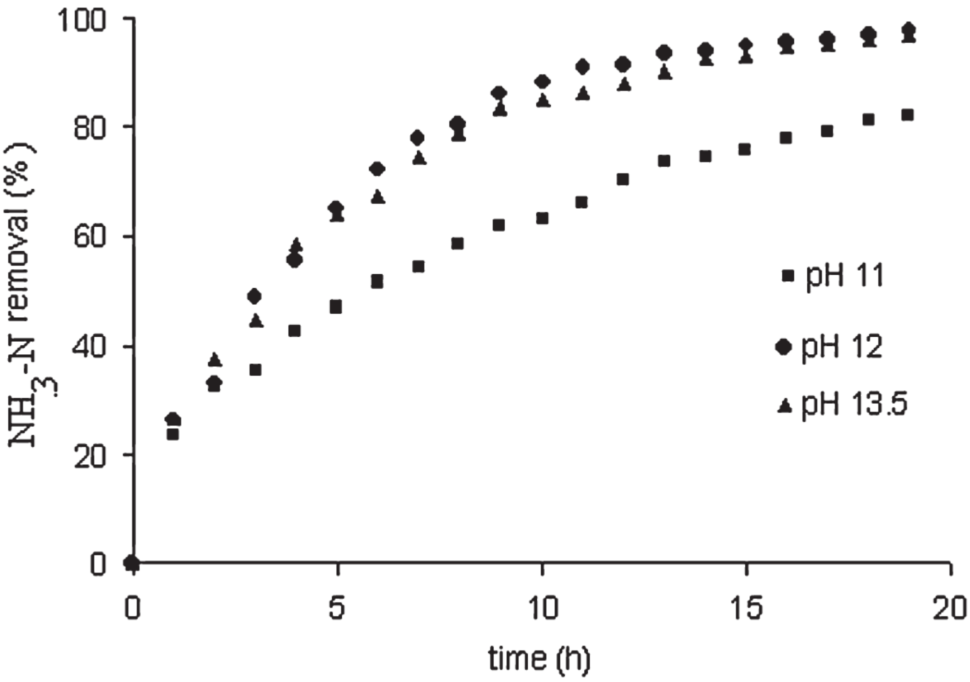

Figure 6 Ammonia removal percentage over time at different pH values. The air stripping and absorption to sulfuric acid solution was done to source separated urine. (Başakçilardan-Kabakci et al. 2007).

Stripping has also some possible negative aspects. Air stripping can result in high energy costs (Batstone et al. 2015). A possible downside in agricultural use of ammonium sulfate from air scrubbing and absorption is the low pH of the product (Vaneeckhaute 2015). Stripping can also result in the presence of some volatile contaminants in the end product, such as PAH compounds (Gasum Biovakka 2016).

To obtain a more condensed product, ammonium sulfate can be crystallized. For air stripping and sulfuric acid absorption of source separated urine, the crystallization of ammonium sulfate was not complicated but it resulted in ammonia loss of 8-10%. This suggested that the product would be preferred as a liquid solution. (Başakçilardan-Kabakci et al. 2007) There is also at least one project that studies the possibility of applying ammonium sulfate with the same machinery than herbicides to overcome the lack of experience of using liquid fertilizers in Finnish agriculture (Ministry of Agriculture and Forestry of Finland n.d.).

Ammonia and nitrate can also be removed by ion exchange using zeolite minerals, but the method might be more used for drinking water treatment (Capodaglio et al. 2015). Ammonia can be removed from wastewaters preloading the ion exchange minerals with potassium ions. When using potassium sulfate, ammonia is recovered as ammonium sulfate. (Sutton et al. 2011)

There are several membrane technologies for nutrient recovery from wastewater, including membrane distillation and electrodialysis, among others. Membrane distillation consists of a hydrophobic membrane which lets gases through. This means that it can be used for recovery of water as vapor or ammonia. Ammonia can be captured in an aqueous solution or by stripping using for example sulfuric acid. A possible risk associated with this technology is that the membrane can also let volatile fatty acids or other contaminants through. Electrodialysis combines ion exchange and membranes. An ion-exchange membrane separates the wanted nutrients, such as ammonia, from the wastewater. (Xie et al. 2016)

2.3 Image of fertilizers produced using resource recovery

2.3.1 General

This section concentrates on acceptance of land application or fertilizer use of human waste-based products. There are several studies about different fertilizer products produced recovering nutrients from wastewater or dry toilets. The studies include data from several countries in different continents. Part of the data of these studies is collected from interviewing professional farmers.

The studies concerning public acceptance and resource recovery from wastewater are mainly about sewage sludge, source separated urine and wastewater treatment plant effluent. Attitudes towards fertilizers that are produced from waste streams but then further treated to inorganic fertilizers were not available. The opinions about them might be different than those presented in this thesis and should be studied.

2.3.2 Farmers’ perception of sewage sludge-based fertilizers

The attitude of farmers might be critical to resource recovery-based fertilizers, even though it should be noted that the farmers are also a diverse group with multiple different views on the subject. The farmers and their views might be represented by farmer organizations. For example, in Sweden the Federation of Swedish Farmers advised farmers that sludge should not be used as a fertilizer in 1999, which led to cereal buyers not to accept sludge use either. (Bengtsson and Tillman 2004)

In Finland, The Central Union of Agricultural Producers and Forest Owners recommends on their web page that municipal sludge should only be used as ash (MTK The Central Union of Agricultural Producers and Forest Owners 2017). Many Finnish grain buyers have also prohibited the use of sludge in the cereals sold to them (Fazer Mills 2018, Hankkija Oy 2019, Raisio Group , Viking Malt Oy 2018). On the other hand, there are other parties which promote the use of sewage sludge-based fertilizers, such the Finnish Water Utilities Association (Seppälä and Liikanen 2019).

In New Jersey, 50 farmers were interviewed about their thoughts of sewage sludge as a fertilizer. Out of them, only 5 had applied sewage sludge at some point and only one still was doing so – even though he was not aware that there was sewage sludge in the fertilizer he used. Most of the farmers did not even consider the possibility of applying sewage sludge as a fertilizer. (Krogmann et al. 2001)

The major concerns of the farmers in New Jersey regarding sewage sludge fertilizer use were public acceptance, the uncertainty related to sewage sludge fertilizers, possible hazards (heavy metals) and odors. Additionally, one major reason for not applying sewage sludge was that it was not available for the farmers. The positive effects on costs and quality of land and crops were seen as positive sides for sewage sludge fertilizers. Despite the positive aspects, the farmers were not willing to consume food fertilized with sewage sludge products. (Krogmann et al. 2001)

2.3.3 Private gardeners' perception of sewage sludge-based fertilizers

For private people, views on resource recovered fertilizers can be diverse. In a study made by Robinson et al. (2012), people living in the southeast part of the United States did not think that possible advantages of sewage sludge use as land application would compensate for the possible hazards. The majority of the people interviewed answered correctly to less than 50% of the factual questions about sewage sludge (referred to as biosolids in the study). The attitudes of the people interviewed regarding sewage sludge use in food production were overall negative. There were three different food production categories: pastures for animals raised for human consumption, food crops and home vegetable gardens. The results by gender are presented in Table 3. (Robinson et al. 2012)

Table 3 Attitudes regarding sewage sludge in food production in southeast USA. The attitudes represent mean values of each gender. Edited from Robinson et al. 2012.

Sludge reuse application	Males' attitudes	Females' attitudes
Pastures for animals raised for human consumption	Neutral	Negative
Food crops	Negative	Negative
Home vegetable gardens	Negative	Negative

The Americans of the southeast part of the country had neutral attitudes towards public health risks outweighing the upsides of sewage sludge usage. Nevertheless, females were opposed to applying sludge to land. Males had a neutral response to this question as well. Both genders still felt like the possible risks of sludge reuse were not properly informed and they were concerned about sludge containing hazardous microorganisms. The people opposed to sludge land application did not feel confident of the sludge treatment being adequate in order to ensure the hygienic quality. (Robinson et al. 2012)

2.3.4 Image of source separated urine fertilizers

In the past few years, there have been many studies from many parts of the world regarding source separated urine as a resource recovery fertilizer. A European review studied public acceptance of using urine as a fertilizer. Part of the questioned people were using urine separation toilets. 85% of the approximately 900 answers were positive regarding urine use as fertilizer. The acceptance was 50% among the questioned farmers, but only about one third would buy or use urine fertilizers. According to the review, a majority of people would also buy food grown using urine as a fertilizer. Most of the farmers would only use it if it was cheaper than conventional fertilizers, or free. Hygienic quality, pharmaceuticals and micropollutants were concerns related to urine fertilizers. (Lienert and Larsen 2010)

In Kenya, users and non-users of urine diversion dehydration toilets (UDDTs) were willing to use the dried feces and urine as fertilizers in their farms. The users had more information about the UDDTs and 88% of them were open to buy UDDT fertilizers. 67% of the less-informed non-users were open to buy UDDT fertilizers to their farms. (Uddin et al. 2012)

On another study conducted in Muslim countries, the willingness to use UDDT fertilizers was 100% of the UDDT users and 61% among non-users. (Uddin et al. 2014)

The people in both of these studies had low average income. In addition, handling human waste was socially unacceptable at first in Kenya and the Muslim countries studied (Uddin et al. 2012, Uddin et al. 2014) In Kenya, after raising awareness and education, this problem was mostly overcome (Uddin et al. 2012).

In a study conducted by Simha et al. (2018), 1252 people from the VIT University in India were interviewed about their attitudes towards human urine and its fertilizer use. While 55% thought of urine as a fertilizer, only 44% would be willing to use food that is grown using urine as fertilizer. 80% of the people thought, nevertheless, that urine could be treated so that it would be safe. (Simha et al. 2018)

3 Materials and methods

3.1 The treatment process

As told in the Introduction chapter, the NPHarvest process has two parts and they serve to produce separate end products. The first part, pretreatment, treats the incoming water so that the solids are coagulated and separated to sludge. The sludge is then further treated to ensure hygienic quality and better fertilizing properties. This is done by adjusting the pH to 12 and dewatering the sludge. Three most promising ideas of dewatering and pH adjustment were tested. The different methods are discussed in more depth in the next sections.

After pretreatment, the liquid fraction goes to the membrane reactor to produce ammonium sulfate. This thesis will examine the quality of the ammonium sulfate produced with a new custom-made pilot reactor shown in Figure 7. In addition to what can be seen in Figure 7, the reactor consists of pH adjustment and an equalization tank.

Figure 7 The membrane reactor in Viikinmäki wastewater treatment plant. On the left, the actual reactor and on the right, the acid container.

3.2 Influent water

The influent water in the piloting phase was reject water coming from Viikinmäki wastewater treatment plant. Viikinmäki wastewater treatment plant has an activated sludge process with denitrification and nitrification. Simultaneously with the activated sludge process, phosphorus is precipitated chemically with ferrous sulfate. Sludge is sedimented in a primary and secondary clarifier as raw and excess sludge. Sludge is digested in a mesophilic process before dewatering with centrifuges. A polymer is added to the dewatering process. The reject water is the water coming from the centrifuges, which is then led back to the beginning of the main treatment process. (Helsinki Region Environmental Services Authority 2017) The whole treatment process can be seen in Figure 8.

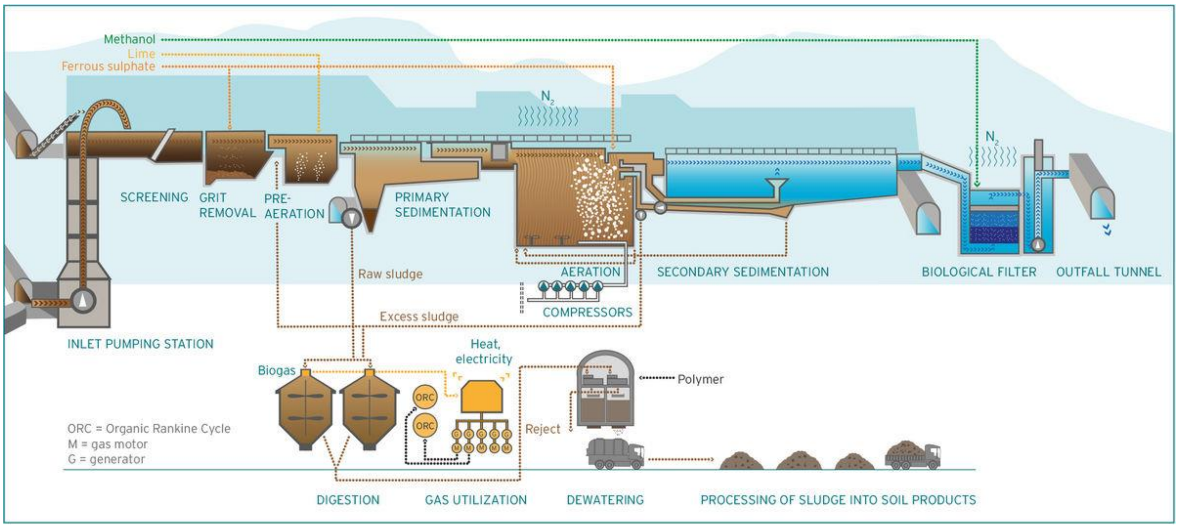

Figure 8 Viikinmäki wastewater treatment plant process (Helsinki Region Environmental Services Authority 2017).

Viikinmäki wastewater treatment plant treats the wastewater of approximately 800 000 people and the industries in Helsinki area. The incoming wastewater flow is 280 000 m^3/d as average. Over 95% of the total phosphorus and over 80% of the total nitrogen is removed in the process. (Helsinki Region Environmental Services Authority 2017)

The quality of the Viikinmäki reject water has quite much variation. For example, the variation in suspended solids is from 550 mg/l to over 2 g/l. On average, the suspended solid content is approximately 1 g/l, total phosphorus and orthophosphate 14 mg/l and 1.2 mg/l respectively and total nitrogen and ammonium nitrogen 910 mg/l and 720 mg/l respectively. (Sah 2019) This sets the starting point for the NPHarvest treatment process. Suspended solids and ammonium-nitrogen concentrations are quite high while phosphorus content relatively is low, especially the soluble orthophosphate.

3.3 Experiment details

The chemical dosing of the pretreatment process was already optimized in previous steps of the NPHarvest project. The sludge coming from the pretreatment unit had still quite low total solids concentration – only about 1-1.5%. To improve the product quality, the TS concentration should be considerable higher. In order to achieve that, different dewatering tests were conducted. In addition, the NPHarvest sludge does not have sufficient hygienic quality after the pretreatment (Sah 2019). The chosen method for hygienization was raising pH to 12 with calcium products. The different paths used for further treatment of the NPHarvest sludge products are shown in Figure 9.

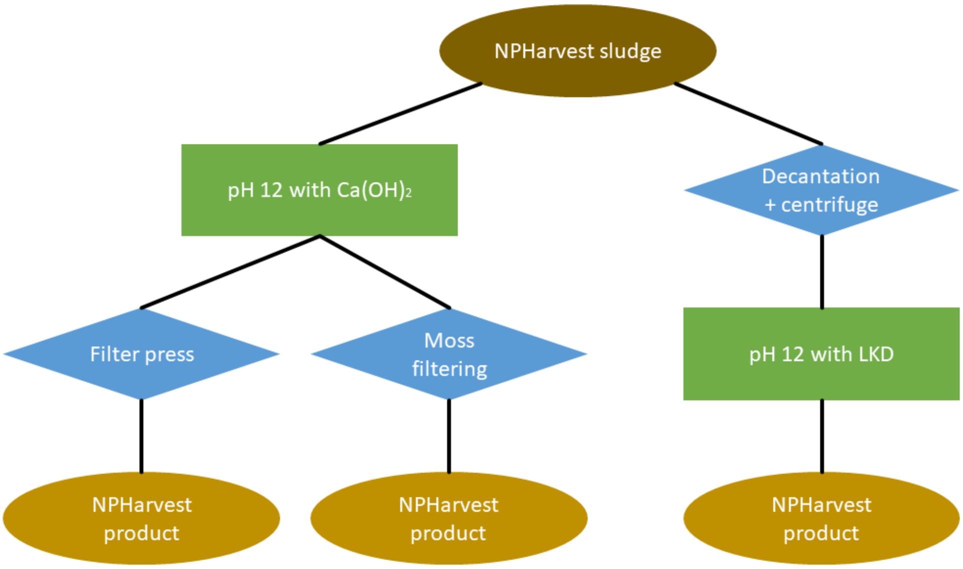

Figure 9 Diagram of the further treatment paths of NPHarvest sludge products. Dewatering methods are in blue diamonds and hygienization methods in green boxes.

In addition to developing the pretreatment process, the membrane reactor was tested for ammonium sulfate production. The earlier tests in the NPHarvest project, which have been conducted with membranes, have been in a much smaller scale. The volume of the new reactor is 150 times bigger than the earlier devices. As the pretreatment process was still in a smaller scale, part of the membrane tank volume was filled with source separated urine, which does not require pretreatment apart from pH adjustment.

3.4 Dewatering tests

3.4.1 General

To improve the product quality of the NPHarvest process, TS concentration had to be increased. A higher solid content means lower transportation costs. In addition, a more concentrated fertilizer decreases the volume of fertilizer needed for crops. The goal was to achieve a TS concentration of 10-20%.

The identified methods for dewatering were centrifuging, filtering and using a moss growing medium as a filter. In preliminary tests with unhygienized NPHarvest sludge, the laboratory scale centrifuge performed better than the laboratory scale filtration. Unfortunately, a centrifuge suitable for dewatering easily about 50 l of sludge was not available. Because of that, filtering was preferred over centrifuging in this phase of the project.

3.4.2 Filtration and centrifuging

In order to choose the best filters, the particle size distribution of the sludge was needed. The analysis was conducted with the laser diffraction device Malvern Mastersizer 3000. The test was performed five times using water as dispersant and the program calculated the average values of these tests. The used scattering model was a Fraunhofer model. The effect of ultrasound was tested as well.

After the particle size distribution analysis, some filtering tests were planned. The selected filter was a filter press testing device provided for the tests by Outotec (Figure 10). The tests were performed to NPHarvest sludge before and after hygienization with calcium hydroxide. The hygienized sludge was easily filtered. In Figure 9, this method corresponds to the left-side product. The unhygienized sludge turned out not to be suitable for filtering.

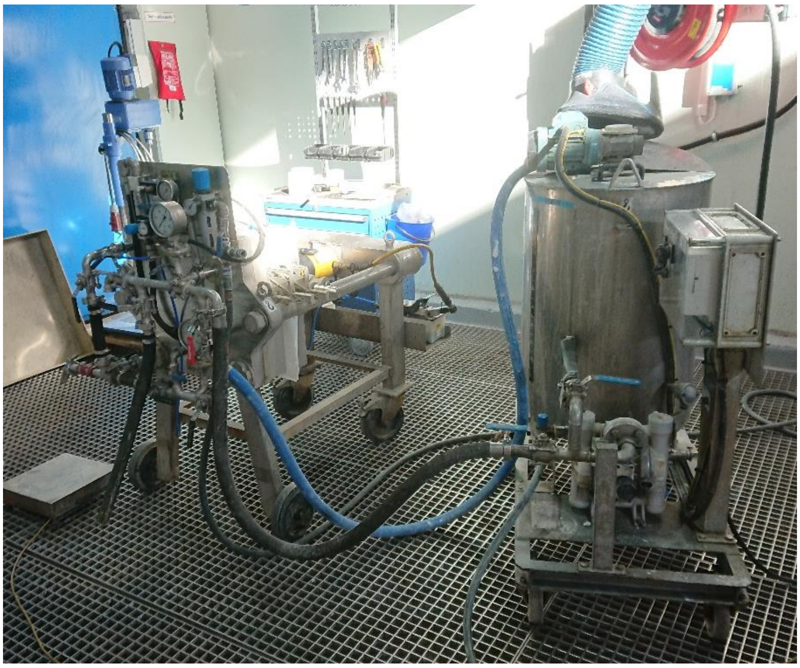

Figure 10 Outotec filter press testing device. The filter part is on the left and sludge tank and pumping on the right.

The filtering tests were done first with a smaller testing device with a filtration area of 0.02 m^2. As a result, suitable filtering conditions were determined. The cake resulted to have a smaller water content that was originally thought, which allowed the pressing part to be limited to one minute and air drying was not needed at all. The pressure in the pressing phase was 12 bar in all the tests. Most of the hygienized sludge was filtered after the preliminary tests with the device in Figure 10, which has 0.27 m^2 filtration area.

Due to problems in filtering the sludge before hygienization, a lab scale centrifuge was used to dewater the NPHarvest sludge after decanting most of the extra liquid. This further treatment path shown in the right side of Figure 9. The centrifuging conditions were 10 500 rpm for 4 minutes and 0.5 l of sludge at a time.

3.4.3 Growing media filtering

Moss and turf growing media were tested as filters for the $Ca(OH)_2$-hygienized sludge. This path produces the product in the center of Figure 9. Figure 11 shows the moss filter used in the tests. The test filter had a diameter of 0.12 m and it was put tightly in a filtering cone as shown in Figure 12.

Figure 11 Dry diameter 0.12 m moss filter before tests

Figure 12 Moss filter in filtering cone before the tests

The filtering properties were tested by first washing the filters with tap water and then filtering the NPHarvest sludge through the growing media. The volume of the water put up for filtering as well as the water coming out of the filter was measured. The filtering effects were tested by analyzing the turbidity of the filtered water. The sludge going through the moss filter can be seen in Figure 13.

Figure 13 Moss filtering test

After the primary tests with the filters, new tests were performed to compare the different materials. There were four different types of filters: 100% moss filter, 100% fine moss filter, 100% rough moss filter and 50% moss - 50% turf filter. There were four different measurements done for each of the filters to evaluate their performance. The mass of the sludge going through the filter as well as the mass of the water that went through the filter were measured.

Additionally, turbidity and pH of the filtered water were tested to see if the filters let sludge pass through. The pH was measured because in preliminary tests the filtered water had been less basic than the original sludge put through the filter. Thus, low pH values combined with low turbidity indicate that no sludge has passed without proper filtering.

In the tests, each of the filters were put in a 12 cm diameter filtering cone like in the earlier tests shown in Figure 11, Figure 12 and Figure 13. Unlike in the earlier tests, water was now added so that only the surface of the filters was moist. This simulated better the conditions of larger-scale moss/turf filtering. The larger-scale filtering was performed in a box with holes in the sides which allow the extra sludge to escape the system without filtering.

3.5 Testing suitability for fertilizer use

3.5.1 Hygienic quality tests

The hygienization of the sludge was done by raising the pH to 12 either with calcium hydroxide or LKD. After raising the pH, some preliminary coliform bacteria analysis were performed. The analysis was done to the sludge before and after raising the pH with calcium hydroxide using the standard SFS 3016:2011. The tests were performed to different dilutions of both samples.

To be sure of the hygienic quality, samples of the sludge after pH raising but before dewatering were sent to an external laboratory for further testing. The pH was 12 for three hours before it was adjusted to 8 for the hygienic quality analysis. The same analysis were done to the ammonium sulfate solution from the membrane reactor and the incoming reject water. The pH and temperature of the samples taken for the analysis are shown in Table 4.

Table 4 Properties of the samples sent for hygienic quality analysis

Sample	pH	T (°C)
Incoming reject water	7.91	27.4
Ammonium sulfate	0.11	18.4
Hygienized sludge	12.14	33.4

The hygienic quality analysis were chosen so that the requirements of the fertilizer legislation could be tested and the microorganisms that had been detected in the incoming reject water in previous steps of the project were also tested in the NPHarvest products. The chosen microorganisms for the tests were E. coli, Salmonella, Clostridia, coliphages and Legionella. The standards according to which the analysis were performed, are presented in Table 5. The hygienic quality analysis were performed by the Water Microbiology Laboratory of the National Institute for Health and Welfare in Kuopio.

Table 5 Standards of bacteria and virus analysis.

Analysis	Standard/method
E. coli	SFS-EN ISO 9308-1:2014/A1:2017
Salmonella	ISO 19250:2010
Sulfite reducing Clostridia, spores + vegetative	SFS-EN 26461-2
Somatic + F specific coliphages	US EPA Method 1602
Legionella by culturing	National Institute for Health and Welfare method YVESTO11 and YVESTO22 based on ISO 11731:1998
Legionella by PCR	qPCR method

3.5.2 Nutrients and harmful substances tests

The NPHarvest products were sent to outside laboratories to perform quality analysis. The chosen metals and nutrients are based on the requirements of the Finnish fertilizer legislation. The standards of the nutrient analysis are presented in Table 6. MetropoliLab performed the analysis shown in the table.

Table 6 Standards of nutrient analysis.

Analysis	Standard	Uncertainty %
NH_4-N	ISO 7150: 1984, DA	15
Soluble NH_4-N	SFS-EN 13652	20
NO_3-N	Internal method of MetropoliLab	15
Soluble NO_3-N	SFS 3029 DA	20
Total N	SFS-EN ISO 11905-1	15
PO_4-P	SFS-EN ISO 6878:2004	15
Soluble PO_4-P	SFS-EN ISO 6878:2004	20
Total P	SFS 3026 mod. DA	15
Kjeldahl-N	Kjeldahl	7
P	ICP-OES: SFS-EN ISO 11885:2009	25

Metal analysis were done by the standard SFS-EN ISO 17294-2 for the liquid phase analysis and by SFS-EN 16171 for the solid phase analysis. The uncertainties related to the methods were between 20 and 30%. All of the analysis were performed for the three sludge products in Figure 9, the ammonium sulfate solution and the incoming reject water. These analysis were performed by Eurofins Environment Testing.

Organic pollutant tests were selected based on the results from earlier tests in the NPHarvest project. The chosen categories include substances that have been found in one or more of the analyzed samples in earlier tests. In addition to these substances, PAH_{16} analysis was included. The analysis and standards used are presented in Table 7. All the analysis were performed by Eurofins Environment Testing. The analysis were performed to the incoming reject water, ammonium sulfate and hygienized wet sludge with TS 1.7%.

Table 7 Standards of organic pollutant analysis.

Analysis	Standard
Pharmaceuticals	EPA 1694
PFC substances	Eurofins internal method EF 4041 , LC-MS/MS
PAH_{16}	ISO 28540, ISO/TS 28581

3.5.3 Growth tests

Biolan conducted growth tests for the NPHarvest fertilizer products in their greenhouse in Eurajoki. The tested products were the ammonium sulfate solution and the three different sludge products presented in Figure 9. Because of the different properties of the products, different plants were tested for different products as can be seen in Table 8. The tests were run for about one month. The detailed planning of the tests was done by Biolan and a more detailed description of the tests and results can be seen in Appendix 1.

The tests are only preliminary to get an impression of the fertilizing qualities of the products. It should be noted that according to current legislation, sludge fertilizers cannot be used on vegetable crops. Thus, these tests do not represent the use that NPHarvest sludge products could have according to current legislation.

Table 8 Growth tests for the NPHarvest products.

Product	Plant	Testing conditions	Control test
Ammonium sulfate	Cucumber	0.5 dl of ammonium sulfate per 1 l of water	Water
Filtered sludge	Tomato and Chinese cabbage	The product was ground and put 5 ml in one pot and 10 ml in another to act as a reserve fertilizer. Fertilizers (1 g/l) and lime (6 g/l) were added to the turf used both in the control and in the filtered sludge tests.	Biolan herb and seedling fertilizer approx. 10 ml/pot
Centrifuged sludge	Tomato and Chinese cabbage	5 ml/l and 8 ml/l of the product to act as a source of lime.	No control
Moss-filtered sludge	Lettuce	100% moss-filtered sludge 50/50 turf/moss-filtered sludge 80/20 turf/moss-filtered sludge to act as growing media. Lime (6 kg/m^3) and fertilizers were added to the turf (1 kg/m^3).	100% turf

4 Results

4.1 End product optimization

4.1.1 Ammonium sulfate

The ammonium sulfate from the NPHarvest process is considered an inorganic fertilizer, as there are no limitations to the source of these products as long as they have less than 1% of carbon (Berlin 2019). The ammonium sulfate solution had such a low pH that a TOC analysis could not be performed. However, there should not be carbon in any form present if the membrane reactor works optimally. In reality, there might have been some leaking.

The ammonium sulfate that was sent for further analysis was not completely saturated due to time limitations. In the tested solution, NH_4-N content was 5 g/l, while the saturated solution has approximately 30 g/l of NH_4-N. The results presented later in this section can therefore be considered preliminary. This should be taken into account especially in the growth test and nutrient analysis results.

4.1.2 Sludge

General

The NPHarvest sludge products are seen as soil conditioners (Berlin 2019). There were three different products developed using different methods for dewatering and hygienization. The products are shown in Figure 14. This section will present the different characteristics of these products based on the tests presented in the Chapter 3.

Figure 14 All the NPHarvest sludge products. On top, $Ca(OH)_2$-hygienized and filtered with the Outotec filter press, on the bottom left, CaO-higienized and moss filtered, and on the right, centrifuged sludge.

The particle size distribution was tested so that the most suitable dewatering technology could be chosen. In the tests, laser obscuration was 10.35%. Ultrasound did not have a considerable effect on the results. It broke down some of the bigger flocs but the smallest particle sizes remained approximately the same. The results before ultrasound are presented in Figure 15.

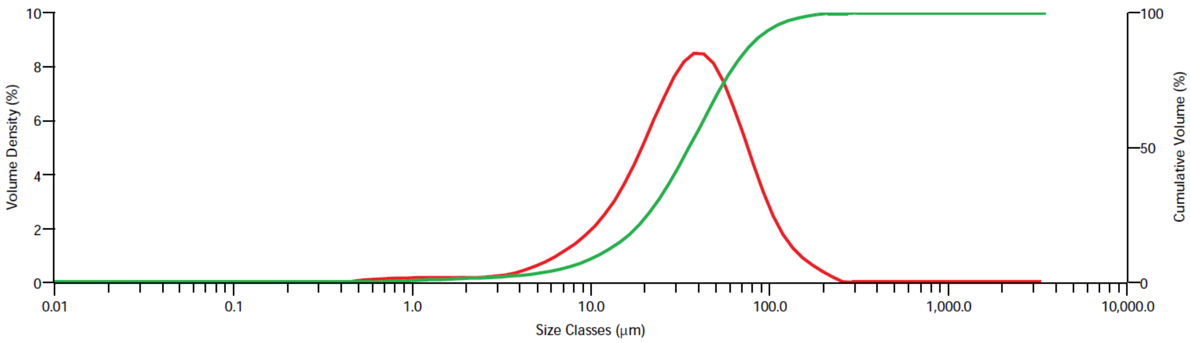

Figure 15 Particle size distribution results. The green line indicates the cumulative values and red line the frequency values.

Calcium hydroxide hygienized and filtered sludge

For filtering, the results of the particle size distribution tests were very good. The shape of the curve and the fact that there is no big variation in the sizes makes the sample easier to filter in theory. In practice, the hygienized sludge was easily filtered but the unhygienized could not be filtered at all.

The preliminary filtration tests for the hygienized sludge were done to about 10 l and the larger-scale tests to about 35 l of sludge. The filtering time was quite short – 6.30 minutes of pumping and 1 minute of pressing with 12 bar for the larger-scale filter press. After all the filtration tests, 1.29 kg of cake was produced with moisture of 43-48%. The filtered product can be seen in Figure 16. The turbidity values of the filtrate in the larger-scale filtration stayed below 3 FNU in the pumping phase and 10.4 FNU after pressing.

Figure 16 The filtered hygienized sludge.

Centrifuged and LKD hygienized sludge

The unhygienized sludge was tested directly with the larger-scale testing device. Two different filter cloth types were tested. The tighter cloth did not let anything through and the looser one let everything through, including the solids. It was concluded that the unhygienized sludge cannot be filtered with filter press.

After the filtering tests, the chosen dewatering technology for the unhygienized sludge was centrifuging. As the settled sludge formed two clear layers – a liquid layer and a thicker sludge layer – it was decided that the liquid layer should be decanted before centrifuging. The wet sludge volume was about 50 liters and after decanting the volume was reduced to about 8 l. The total mass of the sludge after centrifuging was 1824 g. The solids separated well from the liquid as can be seen in Figure 17. In the solids phase, there are two different layers – the heaviest light-colored layer that seems to be mostly unreacted LKD and the darker brown layer of sludge. To ensure the hygienic quality of the product after cetrifuging, the pH was raised to 12 using LKD. The needed amount of LKD was 640 g.

Figure 17 Centrifuging tube with centrifuged unhygienized sludge.

Calcium hydroxide hygienized and moss-filtered sludge

The last dewatering technique tested was moss/turf filtering. In an ideal situation, the solids would distribute evenly in the depth of the moss filter without going through it. An issue was, nonetheless, the clogging of the filter with the solids as shown in Figure 18. A thick layer of solids on top of the filter prevented the excess water to pass through the filter.

Figure 18 The clogged moss filter. The lowest layer is the moss filter and the gray layer above it are the clogging solids. The upmost layers are the liquid sludge and light particles of moss floating on top.

The preliminary moss filtering tests showed that the LKD or other solids do not go through the filter so the filter worked as it was supposed to, even if the solids remained in the top instead of going deeper into the filter. The turbidity values remained in the same magnitude throughout the test. The turbidity results are shown in Figure 19.

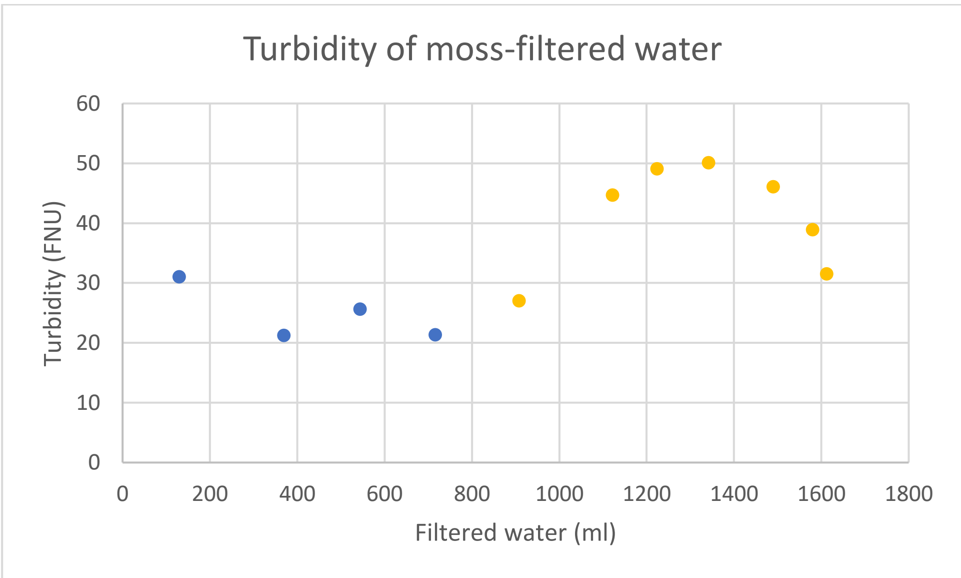

Figure 19 Turbidity measurements of the water filtered through the moss filter. Blue dots are measurements of filtered tap water and yellow dots of filtered sludge.

After confirming that the moss/turf filters indeed work, some additional tests were performed to compare the different filter materials. The results are shown in Table 9. It can be clearly seen that the 100% moss performed best in these tests as it let most water through and the filtered water had the smallest turbidity and pH values which indicate that few solid particles went through the filter.

Table 9 Results of moss/turf filter tests to compare performance of different materials.

	100% moss	Fine moss	Rough moss	Moss-turf mix
Mass of sludge to filter (g) = M1	1305	787	720	955
Mass of filtered water (g) = M2	808	580	482	566
M1/M2	62%	74%	67%	59%
Turbidity of filtered water (FNU)	31	81	65	158
pH of filtered water	9,1	10,5	10,4	10,2

The chosen filter type for the larger-scale moss/turf dewatering was the 100% moss filter. The filtering was done so that the surface was kept moist the whole time. Due to the holes in the sides, the extra sludge on the surface exited the box unfiltered. After the filtration was complete, the moss and sludge were mixed.

Total solids of the sludge products

After performing all the dewatering tests, the total solids of all the three sludge products were analyzed. The results are presented in Table 10. The goal was to have TS concentrations between 10 and 15% so the dewatering worked better than expected with all the different dewatering methods. The 1st and 3rd product were hygienized with calcium hydroxide before dewatering, and the 2nd product was first decanted and centrifuged and hygienized after with LKD.

Table 10 Total solids in the sludge products.

Dewatering method	Hygienizing chemical	Total solids (%)
Filtered sludge	Calcium hydroxide	56
Centrifuged sludge	Lime kiln dust	39
Moss filtered sludge	Calcium hydroxide	18

4.2 Suitability for fertilizer use

4.2.1 Hygienic quality

The preliminary coliform bacteria growth tests showed that hygienizing the sludge by raising pH to 12 with calcium hydroxide for two hours worked. The counted bacteria are presented in Table 11. No colony-forming units were counted for any of the dilutions of hygienized sludge.

Table 11 Preliminary hygienic quality tests for sludge before and after raising pH to 12.

Hygienization	Dilution	Bacteria count (CFU/ml)
No	1:100	0,07
No	1:1000	0,19
No	1:10 000	0
Yes	1:10	0
Yes	1:10	0
Yes	1:100	0
Yes	1:100	0

The broad analysis for hygienic quality were performed in the Water Microbiology Laboratory of the National Institute for Health and Welfare in Kuopio, Finland. The results are shown in Table 12 and the full test report in Appendix 2. As the pH of the ammonium sulfate solution was very low – 0.11 – some of the analysis may not have worked exactly as they are supposed to. The clearest example of the limitations set by pH was the coliphage analysis that could not be performed for the ammonium sulfate sample because the host bacteria needed for the test were destroyed. This was probably caused by the low pH.

Table 12 Bacteria and virus analysis performed on NPHarvest incoming reject water and products.

Analysis	Reject water	Ammonium sulfate	Hygienized sludge
E. coli (CFU/ml)	400	<0.01	<1
Salmonella	detected	not detected	not detected
Sulfite reducing Clostridia, spores (CFU/ml)	4 800	<0.01	2 300
Sulfite reducing Clostridia, vegetative cells (CFU/ml)	18 000	<0.01	3 600
Somatic coliphages (PFU/ml)	42	no results	not detected
F specific coliphages (PFU/ml)	0.03	no results	not detected
Legionella culturing (PFU/ml)	not detected	not detected	not detected
Legionella qPCR genus level DNA (GC/ml)	1 800	not detected	not detected
Legionella qPCR genus level RNA (GC/ml)	5 200 000	not detected	not detected
Legionella qPCR L. pneumophila serotypes 1-15, DNA (GC/ml)	detected	not detected	not detected

The results show that there were no microorganisms alive found in the ammonium sulfate. Reject water contained all of the tested microorganisms. In the hygienized sludge, there were some Clostridia vegetative cells and spores present. The amount was smaller than in the reject water but still rather high.

4.2.2 Nutrients and metals

The nutrient content was analyzed for all the end products. The results are presented in Table 13 and the full test report is in Appendix 3. As could be expected, ammonium sulfate had a high ammonia concentration, even if it was not completely saturated. The filtered sludge has the highest total phosphorus concentration per kg TS when comparing the sludge products, and the moss-filtered sludge the highest total Kjeldahl nitrogen concentration. The differences in the nutrient concentrations are due to the addition of LKD to the centrifuged sludge, which increased the amount of solids without increasing the amount of primary nutrients, and the moss filter, which might have contained some nutrients of its own. Soluble phosphorus in phosphate form could not be detected in the sludge products. The reject water had some phosphate phosphorus.

*Table 13 Results of nutrient analysis. *Nutrients in dry matter. **Soluble nutrients. ***Kjeldahl nitrogen.*

Analysis	Reject water (mg/l)	Ammonium sulfate (mg/l)	Filtered sludge (mg/kg*)	Centrifuged sludge (mg/kg*)	Moss-filtered sludge (mg/kg*)
NH_4-N	770	5 000	61**	621**	1831**
NO_3-N	0.14	-	0.4**	5.3**	2.0**
Total N	960	6 300	7 000***	4 000***	9 000***
PO_4-P	2.9	-	<0.1**	<0.1**	<0.1**
Total P	16	-	720	460	470

A broad metal analysis was also performed to all the end products as well as the incoming reject water. Some of the metals are considered beneficial for plant growth (calcium, for example) and others, harmful substances (like mercury and lead). The results are presented in Table 14. The full test report for the metal analysis as well as organic pollutants is in Appendix 4. All of the metals tested except for boron were detected in the reject water and also in the sludge products. The laboratory gave the results of the centrifuged sludge in mg/l as it had been analyzed as a liquid. In the table below, the values are converted to mg/kg dry matter so that they would be comparable with the results of the other sludge products. The solid content used in the calculations was 39%.

Table 14 Metal analysis results for all the end products and the reject water. The values for the sludge products are presented in mg/kg, while the other values are in mg/l.

Analysis	Reject water (mg/l)	Ammonium sulfate (mg/l)	Filtered sludge (mg/kg dry matter)	Centrifuged sludge (mg/kg dry matter)	Moss-filtered sludge (mg/kg dry matter)
As	0.014	<0.005	3.9	0.097	<1.0
B	<0.05	<0.05	<20	<0.13	<20
Hg	0.00019	<0.0001	0.35	0.05	0.1
Cd	0.00024	<0.0002	0.24	0.0067	0.26
K	82	0.97	1 100	6 154	1 900
Ca	96	6.6	340 000	4 615	35 000
Co	0.02	0.016	1.7	0.36	1.1
Cr	0.015	0.32	13	0.16	1.9
Cu	0.11	0.18	1 500	0.82	12
Pb	0.0035	0.017	230	0.5	13
Mg	30	0.18	6 200	51	2100
Mn	0.082	0.22	2 100	2.8	160
Mo	0.025	0.19	5.1	0.041	<2.0
Na	83	1.4	460	1 615	780
Ni	0.078	1.2	11	0.64	3.8
Fe	19	6.9	5 700	56	2 700
S	34	20 000	3 600	192	1 300
Se	0.0061	<0.0010	<1.0	0.064	<1.0
Zn	0.13	1.2	51	0.5	43

Ammonium sulfate had high sulfur concentrations as can be expected. Additionally, there were some other substances present as well. The solution contained for example calcium and iron. These metals can have entered the system through a leaking membrane or joint. The calcium concentration of the sludge products was high, especially for the filtered sludge.

4.2.3 Harmful organic substances

The harmful organic substances were tested in three categories: pharmaceuticals, PFCs and PAH_{16} substances. The pharmaceuticals and PFCs were tested with extensive packs of tests. In the following tables, the results of these analysis are presented for the substances which were detected. The results of the pharmaceutical tests are in Table 15 and the PFC test results are in Table 16. None of these substances should be present in the sludge if they are not in the reject water. However, some of them might be present in a higher concentration in the sludge products, which has made them detectable in the analysis even if they cannot be detected in the reject water.

It should be noted that the uncertainties of the pharmaceutical testing methods are rather high, 28-55%. The results of the pharmaceuticals were also converted to the unit µg/kg dry matter using 1.7% as the TS content of the sludge. The highest single concentration of a pharmaceutical substance is ibuprofen in hygienized sludge. In the PFC substances, there are no such big differences in concentrations.

Table 15 Results and uncertainties of the pharmaceutical analysis performed.

Analysis	Reject water (µg/l)	Ammonium sulfate (µg/l)	Hygienized sludge (µg/l)	Hygienized sludge (µg/kg dry matter)	Uncer-tainty %
5-methylbenzotriazol	<1.0	2.9	6.6	388	55
Benzotriazol	<4.0	0.81	2.4	141	45
Caffeine	3.2	0.95	5.3	312	44
Sertraline and norsertraline	0.72	0.13	0.39	23	48
Diclofenac	1.4	<0.050	1.3	76	46
Carbamazepine	0.77	<0.050	0.6	35	40
Clozapine	1.1	<0.050	1.1	65	28
Lamotrigine	4.4	<0.050	3	176	48
Losartan	5.4	<0.050	3.7	218	48
Metoprolol	0.53	<0.050	0.56	33	46
Cetirizine	4.7	<0.050	4.1	241	45
Bisoprolol (ß-Adrenergics)	<1.0	<0.10	0.43	25	52
Atorvastatin	<1.0	<0.10	0.59	35	44
Desloratadine	<0.50	<0.050	0.13	8	41
Fenazon	<0.50	<0.050	0.072	4	34
Hydrocortison	<1.0	<0.10	1	59	44
Ibuprofen	<10	<5.0	12	706	44
Quetiapine	<0.50	<0.050	0.24	14	40
Ketoconazole	<1.0	<0.10	0.14	8	43
Mirtazapin	<0.50	<0.050	0.15	9	43
Propanolol	<1.0	<0.10	0.13	8	45
Citalopram	<1.0	<0.10	0.18	11	50

Table 16 Results and uncertainties of the PFC analysis performed.

Analysis	Reject water (µg/l)	Hygienized sludge (µg/l)	Uncertainty %
PFOA	0.008	0.005	22
PFOS	0.021	0.035	24
6:2 FTS	0.015	0.013	31

PAH_{16} substances were present in all the tested samples. Traces of most of the substances could not be detected for ammonium sulfate. The total amount of PAH_{16} substances was higher for the hygienized sludge than for the incoming reject water. All the PAH_{16} results are presented in Table 17.

Table 17 Results and uncertainties of the PAH_{16} analysis performed.

Analysis	Reject water (µg/l)	Ammonium sulfate (µg/l)	Hygienized sludge (µg/l)	Uncertainty %
Acenaphthene	0.05	<0,005	0.067	22
Acenaphthylene	<0,05	<0,005	<0,05	25
Anthracene	<0,05	<0,005	0.063	18
Benzo(a)anthracene	0.05	<0,001	0.07	28
Benzo(b)fluoranthene	0.061	<0,001	0.088	25
Benzo(k)fluoranthene	0.014	<0,001	0.016	27
Benzo(a)pyrene	0.025	<0,00017	0.031	26
Benzo(ghi)perylene	0.034	<0,0005	0.035	17
Dibenzo(ah)anthracene	0.006	<0,0005	0.008	23
Phenanthrene	0.22	0.007	0.31	20
Fluorene	0.059	<0,005	0.079	22
Fluoranthene	0.15	<0,005	0.23	23
Chrysene	0.045	<0,001	0.074	20
Indeno(1,2,3-cd)pyrene	0.013	<0,0005	0.014	17
Naphthalene	0.14	<0,01	0.15	22
Pyrene	0.15	<0,005	0.22	20
SUM	**1.017**	**0.007**	**1.455**	

The hygienized sludge has a high water content. To make comparison to limits or other products easier, the total PAH_{16} content was also calculated as concentration in dry matter. The total solids of the hygienized sludge was 1.7%, the total PAH_{16} concentration in dry matter would be about 85.6 µg/kg dry matter or 0.0856 mg/kg dry matter.

4.2.4 Growth tests

Ammonium sulfate

A month after starting the growth tests, the plants fertilized with ammonium sulfate did not show any difference in growth compared to the control test plant that had been only watered. There were some very sunny days during the tests which injured some leaves of one of the plants. All the plants were watered without adding fertilizers during the sunny days. In the end of the tests, the plants that were only watered grew bigger and the cucumbers they produced were heavier. This can be seen in Table 18.

Table 18 The weight of the cucumbers and height of the stems in the ammonium sulfate growth tests.

Test	Weight of cucumbers (g)	Height of stems (m)
Ammonium sulfate	713 and 512	3.6 and 3.4
Control	1207 and 798	4.2 and 3,5

Nevertheless, it was clear that the cucumber plants that had been only watered suffered from a lack of nitrogen and turned yellowish. The ones that received ammonium sulfate were of a darker green color. This can be seen in Figure 20. The ammonium sulfate solution provided a good source of nitrogen for the plants.

Figure 20 The cucumber plants 1.5 months after starting the growth tests. On the left, the control test plants and on the right, the plants that have received ammonium sulfate. Figure by Biolan.

Filtered sludge

Filtered sludge performed worse as a fertilizer for Chinese cabbage than the fertilizer used in the control test, but in the tests done with tomato, the higher dosage of filtered sludge resulted in the biggest plants. The higher dosage performed better than the lower with both plants. The weights of the plants are presented in Table 19. For the Chinese cabbage, the roots did not seek as much to the fertilizer as they normally do. On the other hand, the tomato roots were good for all of the plants.

Table 19 Weights of the plants fertilized with a higher or lower dose of filtered sludge and in the control test.

Test	Chinese cabbage (g)	Tomato plant (g)
Higher dosage	33.4	26.7
Lower dosage	22.6	18.3
Control test	49.2	22

The Chinese cabbage plants that had been fertilized with the filtered sludge seemed to be lacking fertilizers, but the values of the parameters that represent the amount of nitrogen were similar for the plants fertilized with the filtered sludge and the control test. Similarly, the tomato plants fertilized with the filtered sludge seemed to suffer of lack of nitrogen and in this case, also the N values were lower for the plants fertilized with the sludge compared to the control test. The differences in the plants are presented in Figure 21 and Figure 22. The lack of fertilizers can be seen as yellow leaves.

Figure 21 Chinese cabbage growth test with filtered sludge. The plants are (from left): lower dose of filtered sludge, higher dose of filtered sludge and the control test. Figure by Biolan.

Figure 22 Tomato growth test with filtered sludge. The plants are (from left): the control test, lower dose of filtered sludge and higher dose of filtered sludge. Figure by Biolan.

Centrifuged sludge

The centrifuged sludge did not have a control test. It was used as a replacement of lime for turf and worked fairly well. The results were that the bigger dosage of the product produced bigger plants for both tomato and Chinese cabbage. The weights of the plants are presented in Table 20**Error! Reference source not found.**. The difference in the sizes of the plants can also be seen in Figure 23 and Figure 24. In addition, the bigger dosage resulted in stronger roots for the tomato plant.

Table 20 Weights of the plants fertilized with a higher or lower dose of centrifuged sludge.

Test	Chinese cabbage (g)	Tomato plant (g)
Higher dosage	28.57	17.5
Lower dosage	18.7	12.1

Figure 23 Chinese cabbage fertilized with the centrifuged sludge product. The left-side cabbage has received the higher dosage of fertilizer and the right-side one the lower dosage. Figure by Biolan.

Figure 24 Tomato fertilized with the centrifuged sludge product. The right-side cabbage has received the higher dosage of fertilizer and the left-side one the lower dosage. Figure by Biolan.

Moss-filtered sludge

In the tests performed with the moss-filtered sludge, all the lettuces grew well. The biggest crops were produced when 20% of the growing media was moss-filtered sludge. The weight of the leaves of an average lettuce are presented in Table 21 and the lettuces in the end of the tests in Figure 25.

Table 21 Average weight of the leaves of the lettuces in the moss-filtered sludge growth tests.

Test	Average leaf weight (g)
Turf 100% (control)	75.5
80/20 turf/moss-filtered sludge	78.2
50/50 turf/moss-filtered sludge	56.5
100% moss-filtered sludge	24.6

Figure 25 Lettuces of the moss-filtered sludge growth test. From the left: 100% turf (control), 80/20 turf/moss-filtered sludge, 50/50 turf/moss-filtered sludge and 100% moss-filtered sludge. Figure by Biolan.

5 Discussion

5.1 Sources of uncertainty

For the hygienic quality and organic pollutant analysis, the used sample to represent all the sludge products was wet and $Ca(OH)_2$ hygienized sludge. This is not any of the ready end products and its qualities might be different to those of the dewatered sludge. This seems rather improbable, though, as none of the dewatering methods should increase the amount of these harmful substances and microorganisms in the sludge. In addition, the tested ammonium sulfate was not fully saturated. In the tested solution, NH_4-N content was 5 g/l, while the saturated solution has approximately 30 g/l of NH_4-N.

A factor that could affect the quality analysis is the varying quality of the reject water. In earlier phases of NPHarvest, the quality of the incoming reject water has not been constant and for example nutrient concentrations have varied a lot (Sah 2019). This could be the case for different harmful substances, as well. The results presented in this thesis represent only the quality of the particular samples analyzed.

A clear source of uncertainty are the limitations of the analysis methods. There is room for human error as well as limitations of the analyzing equipment. The samples taken for analysis might also not be representative of the whole product. For example, the wet sludge starts to settle quickly so the samples could have more or less liquid than average if the sludge has started to settle before taking the sample. In addition, some of the analysis were done to just one sample per product, so no parallel tests were done.

Another source of uncertainty is the use of source separated urine mixed with NPHarvest pretreated water in the membrane reactor. The qualities of the end product – ammonium sulfate – should still be the same no matter the source of the ammonium. Skipping the pretreatment was justified, as it serves mostly to separate solids from the incoming water. In wastewater treatment plant reject water there are lots of solids that are hard to separate from the water. On the other hand, urine should not contain solids in amounts that could disturb the membranes.

5.2 Analysis of the results

5.2.1 Legislation limits

Sludge products

The NPHarvest products belong to the type designation groups soil conditioner and inorganic fertilizer (Berlin 2019). These types have different requirements in the Finnish fertilizer legislation. For that reason, the comparison to legislation limits is done in two different tables, Table 22 for sludge products and Table 23 for ammonium sulfate. The centrifuged sludge had been analyzed as a liquid by the outside laboratory. The values used here were converted to mg/kg dry matter so that they would be comparable with the legislation limits.

*Table 22 Legislation limits compared to analysis results for NPHarvest sludge fertilizer products. *From Decree of the Ministry of Agriculture and Forestry 24/11.*

Restricted material	Legislation limit*	Filtered sludge	Centrifuged sludge	Moss-filetered sludge
Cd	1.5 mg/kg dry matter	ok	ok	ok
As	25 mg/kg dry matter	ok	ok	ok
Hg	1 mg/kg dry matter	ok	ok	ok
Cr	300 mg/kg dry matter	ok	ok	ok
Cu	600 mg/kg dry matter	1 500 mg/kg	ok	ok
Pb	100 mg/kg dry matter	230 mg/kg	ok	ok
Ni	100 mg/kg dry matter	ok	ok	ok
Zn	1500 mg/kg dry matter	ok	ok	ok
Salmo-nella	Not detected	ok in hygienized sludge		
E. coli	1000 CFU/g			

As can be seen, the sludge products fulfill almost all the requirements. The concentrations of copper and lead are considerably higher than allowed in the filtered sludge. The values for centrifuged sludge are much lower, even though the product should be almost the same: solids content is higher for the filtered sludge and the hygienizing chemical is different but otherwise they should be entirely identical.

The differences in dosage of the hygienizing chemicals can partly explain the differences in the concentrations – LKD dosage was much higher than calcium hydroxide dosage so the solid part of the filtered sludge has more hygienization chemical in proportion. The samples of sludge, which were then further treated in the two different processes, were taken on the same day so there should not be differences in the incoming reject water. One possibility is that the filtering testing device at Outotec contained traces of metals, which were then detected in the filtered sludge. Outotec tests for example samples from mines with their devices and these samples can have high metal concentrations. The centrifuged sludge was also analyzed as a liquid and the filtered and moss-filtered sludges as solids. The differences in the analyzing methods could also cause differences in the results, even if the centrifuged sludge results were converted to the same unit.

Ammonium sulfate

For ammonium sulfate, all the harmful substance concentrations and bacteria count were within the legislation limits, as can be seen in Table 23. The total solids content of the solution could not be determined, so the legislation limits are compared to the concentrations in the whole solution. A better point of comparison could be the EQS maximum allowed concentrations in aquatic environments (Decree of the Finnish Government 1308/2015) that are also shown in Table 23. The metal traces found in the ammonium sulfate solution are well below these limits. After running the membrane reactor for a while, it was observed that the amount of liquid in the acid container was higher than it should be when compared to the amount of acid that was put in the reactor. It can be deduced that the harmful substances might have entered the system from a leaking membrane or joint. This would explain the presence of metals that should not be able to enter the ammonium sulfate solution tank without a leak.

*Table 23 Legislation limits compared to analysis results for ammonium sulfate. *From Decree of the Ministry of Agriculture and Forestry 24/11. **From Decree of the Finnish Government 1308/2015.*

Restricted material	Legislation limit*	MAC EQS (µg/l)**	Ammonium sulfate
Cd	1.5 mg/kg dry matter	0.45	ok
As	25 mg/kg dry matter		ok
N for inorganic primary nutrient fertilizers with one nutrient	>3%		6 300 mg/l → ~0.63%
Hg	1 mg/kg dry matter	0.07	ok
Cr	300 mg/kg dry matter		ok
Cu	600 mg/kg dry matter		ok
Pb	100 mg/kg dry matter	14	ok
Ni	100 mg/kg dry matter	34	ok
Zn	1500 mg/kg s dry matter		ok
Salmonella	Not detected		ok
E. coli	1000 CFU/g		ok

For the solution to be considered an inorganic primary nutrient fertilizer of one nutrient, it should have a much higher nitrogen content. The acid was not fully saturated when the sample for all the tests performed in outside laboratories was taken. Had it been saturated, the nitrogen content would also be higher. In addition, the water content of the product could be fixed so that the nutrient concentration would be over the 3% required by the legislation. The used sulfuric acid used in the full-scale reactors would probably be stronger, for example two or three molar instead of a molar acid used in these tests, which would increase the amount of nitrogen in the product. The sulfur concentration in the ammonium sulfate is considerable, approximately 2% of the wet weight.

5.2.2 Hygienic quality beyond legislation requirements

Even though the hygienic quality of the NPHarvest products is within the limits set in the legislation, the sludge products had other harmful microorganisms. The Clostridia analysis showed that there were both spores and vegetative cells present in the hygienized sludge. These more persistent microorganisms should probably also be controlled by the legislation to ensure fertilizer safety. The draft Strubias report suggests limits for more microorganisms than the current legislation, including Clostridia (Subgroup of the Commission expert group on Recovery Rules for Fertilising Products 2018). The ammonium sulfate solution did not have any microorganisms detected.

For the hygienized sludge to actually be hygienic, the hygienization process should be improved. The samples that were sent to the analysis were hygienized with calcium hydroxide elevating the pH to over 12 for three hours. This is not seen as a good enough process to ensure hygienic quality. Instead, if the hygienization time is short, the chemical used should be calcium oxide, which also elevates the temperature. (Vieno et al. 2018) When using calcium hydroxide, the pH should be kept over 12 for at least 48 hours (Peltonen et al. 2013), but even when the pH is kept over 12 for several months, the hygienic quality could be insufficient (Vieno et al. 2018).

5.2.3 Nutrients and growth tests

The secondary and micronutrients concentrations in the sludge products are quite high, especially the calcium concentrations. On the other hand, the primary nutrient contents in the sludge products are rather low. This is probably due to the fact that the nutrients in the incoming reject water were quite low as well. The phosphorus is chemically precipitated in the Viikinmäki wastewater treatment plant, so it exits the system with the dewatered sludge instead of being in the reject water. With a different treatment process, the reject water could have quite high phosphorus contents and in that case, the NPHarvest sludge products could also be richer in phosphorus. The nitrogen concentration of the sludge might still be low as the nitrogen is harvested in the membrane reactor. The pretreatment process is designed mostly to remove solids and phosphorus from the incoming stream.

The results of the growth tests reflect the results of nutrient analysis: in the filtered sludge there was lack of plant available nitrogen for optimal growth. It might also work better as a longer-time fertilizer as the phosphorus in the sludge is chemically precipitated. In addition, the centrifuged sludge seemed to work as a source of calcium. As both the filtered and centrifuged sludge contained high concentrations of secondary and micronutrients (such as calcium and magnesium), they might be more suitable to be used together with a more effective NPK fertilizer.

As stated before, the ammonium sulfate solution was not fully saturated when the samples for the analyses were taken. This could be the cause of the questionable fertilizer properties in the preliminary growth tests. Even though the plants of the control test that had only been watered suffered from nitrogen loss, they were bigger and produced bigger cucumbers than the ones fertilized with the ammonium sulfate solution.

5.2.4 Harmful organic substances

PAH substances and PFCs

The NPHarvest products were tested for many organic pollutants. The draft version of the Strubias report presents a limit value for the PAH_{16} substances: 6 mg/kg dry matter of PAH_{16} (Subgroup of the Commission expert group on Recovery Rules for Fertilising Products 2018). The NPHarvest products would fulfill this requirement, as the total amount of PAH_{16} substances was approximately 0.086 mg/kg dry matter. In a study that analyzed harmful substances in Finnish wastewater sludges, the PAH_{16} total concentrations were as average between 0.65 and 2.99 mg/kg dry matter, depending on the sludge treatment method (Vieno 2015). Thus, the amounts in NPHarvest sludge can be considered quite low.

There were no PFC substances in the ammonium sulfate solution and the concentrations in reject water and hygienized sludge were low. In hygienized sludge, the total amount of the tested PFC substances was 3.1 µg/kg dry matter. In Finnish wastewater sludge, the total PFC content was between 6 and 45.7 µg/kg dry matter (Vieno 2015). In conclusion, the tested PAH and PFC substances do not seem to be present in the NPHarvest products in alarming amounts.

Pharmaceuticals

As for the pharmaceuticals present in the NPHarvest products, the uncertainties of the methods are quite high. The results show that out of the tested samples, the hygienized sludge had the highest number of pharmaceuticals detected, in total 22 different substances. This can be due to the higher solids content of this sample compared to the others. As a comparison: in some studies, there have been dozens of different pharmaceuticals in wastewater or sewage sludge (Vieno 2015). Of course, the amount of tested pharmaceuticals might have been bigger in those studies than in the analysis of this master's thesis. Ammonium sulfate had just a couple of detectable pharmaceuticals. As with the previous results, the presence of pharmaceuticals in the ammonium sulfate solution is a sign of a leak somewhere in the reactor as pharmaceuticals should not be present if the process worked perfectly. The number of detected pharmaceuticals in the incoming reject water was in between ammonium sulfate and the sludge.

According to Vieno (2015), 36 different pharmaceuticals were found in samples of Finnish sewage sludges from different wastewater treatment plants. Eight of the pharmaceuticals found in NPHarvest sludge were also present in these samples. Half of these substances were present in more or less the same concentrations in NPHarvest sludge and the Finnish sewage sludges that were tested. The concentration of three substances was lower in NPHarvest sludge than in average in the tested Finnish sludges. The ibuprofen concentration of NPHarvest sludge was higher than the concentrations found in Finnish sewage sludges on average. (Vieno 2015)

Pharmaceuticals in fertilizers are not limited by the Finnish legislation. Thus, it is hard to know what concentrations are considered a risk for human, animal or environmental health. The environmental effects are estimated with PNEC values (predicted no effect concentration). The values vary greatly in different studies and the limit values of most of the detected pharmaceuticals are either not defined or not easily accessible. Nevertheless, the ibuprofen concentration in the hygienized sludge and the diclofenac concentration in reject water and hygienized sludge exceeded the PNEC values of at least one study. These substances had relatively low PNEC values. (Äystö et al. 2014, Matamoros et al. 2015) Table 24 shows a comparison of the results of the performed analysis to PNEC values from literature.

*Table 24 Pharmaceutical analysis results compared to some PNEC values. *Matamoros et al. 2015. **Äystö et al. 2014.*

Analysis	Reject water (µg/l)	Ammonium sulphate (µg/l)	Hygienized sludge (µg/l)	PNEC* (µg/l)	PNEC** (µg/l)
5-methylbenzotriazol		2.9	6.6	51.6	
Benzotriazol		0.81	2.4	19	
Caffeine	3.2	0.95	5.3	46	
Diclofenac	1.4		1.3	22	0.1
Carbamazepine	0.77		0.6	76.3	4.92
Metoprolol	0.53		0.56		58.3
Ibuprofen			12	9.02	7.1

All the harmful substances found in the NPHarvest products must have come with the incoming reject water. This means that the substances in these products are also present in the Viikinmäki sludge. Sewage sludge fertilizers are considered safe to use, so the pharmaceuticals found in the NPHarvest products should not be alarming either. When examining the results of the analyses performed for this thesis, it is important to remember that only one sample of the each product was analyzed so these results are only preliminary.

5.3 Further treatment of NPHarvest products

For the centrifuged and LKD-hygienized end product it could be possible to granulate it to improve its transporting properties, but this should be further examined in order to ensure that granulation works for this product. In the testing phase, the optimal grain size has to be considered so that the products could fit the spreaders currently in use. The other sludge products could be used as such, as long as the hygienic quality is ensured. The ammonium sulfate solution could be either used as a liquid fertilizer or granulated. In the next phases of the project, a suitable form for both field application and private garden use should be found for the products.

According to Bloem et al. (2017), the distance that is reasonable for the transportation of resource recovery-based products might not be very long: only about 50 km for dewatered sludge. Figure 2 in the literature review section illustrates these distances. It should be kept in mind, though, that the NPHarvest sludge products are further processed than sewage sludge so the distance could be longer. In any case, the possible savings coming from using NPHarvest products should be higher than the transportation costs. To estimate these savings, a more profound analysis of the costs for the consumers of the products should be done. The literature review on attitudes towards resource recovery-based fertilizers also showed that farmers might not be willing to pay anything at all for these products even though they might be willing to use them.

Before transportation in order for the products to reach the customers, also packaging and marketing should be done. In the next phases of the project, these are aspects that should be considered. For the best option, it would probably be wise to cooperate with an actor in the fertilizer industry for their expert knowledge on how to get the products to the market.

5.4 Further development of NPHarvest process

5.4.1 The whole NPHarvest process

It was clearly noted that the scale of the current pretreatment unit is too small compared to the membrane reactor. Especially the settling tank had such a small diameter that the incoming treated water caused turbulences in it. This affected negatively the sludge settling and thus, the achieved TS concentration of sludge. In 2020, the pretreatment unit will be upscaled to match with the membrane reactor's capacity as part of the next phases of NPHarvest.

Regarding the current NPHarvest process, there is pH adjustment in two separate places. First, the pH of the sludge must be 12 to ensure hygienic quality. In addition, the pH of the liquid going to the membrane reactor is also raised to 12. To make the process simpler, the pH adjustment could be in the pretreatment unit so that the pH of the whole incoming reject water is raised to 12. The possible issue with this is that the dissolved ammonium starts to form gaseous ammonia in high pH environments. To avoid the ammonia from leaving the system before the membrane reactor, all the basins after pH adjustment should be covered tightly.

However, if the wanted end product is first dewatered and then hygienized with LKD, pH should not be adjusted until after dewatering. This treatment method was proven to be more complicated than adjusting the pH before dewatering. The upside of using LKD is the lower price and the circular economy aspect: using a side product that does not have as much other possible uses.

5.4.2 Pretreatment and dewatering

The processes to further treat the sludge from NPHarvest pretreatment could still be improved. For example the filtration process has some unresolved issues. In the filtration tests, the hygienized sludge performed really well while the unhygienized did not get filtered at all. The main difference between these two samples is the use of calcium hydroxide for hygienizing. This also raises the pH: for the hygienized, it was over 12 and for the unhygienized, between 7 and 8. The difference in filtering properties could be due to the presence of calcium hydroxide and its coagulative effects or the pH could affect the sludge particles and make them tighter. This should be further studied to better understand the dewatering conditions of the sludge.

The third sludge dewatering process, moss filtering, could also be further improved. The current method for using the moss – watering the surface slowly – might not be that practical in full scale processes. In the NPHarvest steering group meeting on the 6th of June, 2019, it was proposed that instead of using the moss as a filter, it could also be first mixed with the sludge and then dewatered. This should also be further examined to ensure the effectiveness of the method. If, however, the current method for moss usage is preferred, the used moss plate should be thinner. Most of the filtered sludge stays in the surface of the filter so using 5 cm thick filters is not necessary. Thinner filters would increase the amount of sludge in the mixed product.

5.5 Image of wastewater-based fertilizers

The literary review revealed that a general public opinion on resource-recovered fertilizers is hard to form. The attitudes towards resource recovery products can be different in different parts of the world. All the results cannot necessarily be directly used in Finland.

In image matters, there are two separate groups to consider: professional farmers and private gardeners. For farmers, on top of their personal opinions they have to consider the opinions of their clients. Some farmers are against resource recovered fertilizers and some grain buyers refuse to buy crops fertilized with sewage sludge-based products.

The other possible buyers are the private gardeners. Based on the literature review, it should be expected that they might prefer more conservative fertilizer products. The better people know resource recovery-based fertilizer products, the more positive attitudes they can be expected to have. Thus, information about the products should be easy to access and easy to understand for people without much expertise in fertilizers. Of course, this means that the properties of the products have to be good and safe.

Besides the division between the user groups, the product types could also be a dividing factor when considering the image of resource recovery-based fertilizers. In the NPHarvest products, the ammonium sulfate solution is a very pure product as it contains almost solely ammonium sulfate. Of course, there is always the risk of the membranes not working properly and some other substances getting mixed in the solution. Nevertheless, it is in essence an inorganic fertilizer so attitudes towards it can be very different when compared to soil conditioners made from sludge or other waste streams. Until this has been studied more profoundly, it should be considered that the ammonium sulfate solution is seen as the other resource recovery fertilizer products.

Another clear factor affecting public opinions on the NPHarvest products is the source of the incoming water. According to Dahlin et al. (2017), sewage sludge-based fertilizers have more negative associations than other sources of biogas digestate, such as grass or animal manure. Even though this master’s thesis concentrates on the Viikinmäki wastewater treatment plant reject water, the NPHarvest process could be used to a number of other waste streams, for which public perception might be more positive.

6 Conclusions and recommendations

The goal of this thesis was to study the quality of the NPHarvest products, the optimization possibilities for resource recovery fertilizers, and the future demands for public image and pollutants for resource recovery fertilizers. The literary review covered the legislation in Finland and the EU, the optimization possibilities and the image issues of resource recovery fertilizers.

Optimizing resource recovery fertilizer products has many sides. An optimal product would have a reasonable price, high nutrient content and low content of harmful substances and pathogenic microorganisms, good fertilizer qualities, and the form of the product would be suitable for the users. The current legislation does not restrict other risks in fertilizers than harmful metals and two indicator bacteria, E. coli and salmonella. However, pollutant legislation is likely to become stricter. For example, the control of PAH_{16} substances has already been in the preparatory work of new EU legislation.

Regarding the image of resource recovery-based fertilizers there are two sides. On the one hand, circular economy is promoted even in the new EU fertilizer regulation and on the other, there can be negative attitudes towards resource recovery-based fertilizers and sewage sludge fertilizers are prohibited by some grain buyers. Informing possible users about the properties and ensuring the safety of the products could help in creating a positive image of resource recovery fertilizers. The image of further treated inorganic resource recovery-based fertilizers should be studied as it can be different than the image of the products that have been studied so far.

The experimental part of this thesis was performed in Viikinmäki wastewater treatment plant. The NPHarvest process was run for the reject water of the plant. There are two consequent parts in the process: the pretreatment part, which produces sludge, and the membrane reactor, which produces ammonium sulfate. To improve the qualities of the sludge as a fertilizer product, it had to be hygienized and dewatered. Three different methods were tested for hygienizing and dewatering: hygienizing with calcium hydroxide combined with a filter press dewatering process, dewatering by centrifuging before hygienizing with LKD, and calcium hydrozide hygienization followed by moss filtering.

To evaluate the NPHarvest products, various analyses were performed. The safety of the products was analyzed with metal, organic pollutants and hygienic quality tests. In addition, the nutrients were analyzed and fertilizer properties were measured in growth tests.

The qualities of the products were mostly good and there are quite straightforward methods that could improve them. The first priority is ensuring the hygienic quality. The hygienized sludge fulfilled the legislation requirements for hygienic quality, but there were some more persistent pathogens present that are not restricted in legislation. Thus, the current hygienization process should be reconsidered. Either the used chemical should be changed to calcium oxide or the hygienization time extended.

Additionally, the sludge products had low nitrogen and phosphorus concentrations, even though the concentrations of some secondary and micronutrients were considerable. In the growth tests, the filtered sludge did not provide enough plant-available nitrogen. Based on the tests performed, it is possible that the sludge products would work better as a source of calcium and other secondary nutrients than as primary nutrient sources.

It should also be noted that these results can only give a preliminary idea of the qualities of the products made from Viikinmäki reject water. The NPHarvest process could be used on other sources, too. With another waste source, the nutrient concentrations in the incoming water and, consequently, also in the products could be higher.

The ammonium sulfate solution was not fully saturated when the samples for the analyses were taken. This could be the cause of the questionable fertilizer properties in the preliminary growth tests. Even though the plants of the control test that had only been watered suffered from nitrogen loss, they were bigger and produced bigger cucumbers than the ones fertilized with the ammonium sulfate solution. The nitrogen content should be higher so that the product would be considered a one primary nutrient fertilizer. This could also be achieved by saturating the sulfuric acid in the membrane reactor and by using a stronger acid.

The organic pollutants that were tested were not present in high concentrations in the products, except for the elevated concentration of ibuprofen in the hygienized sludge. The PAH_{16} concentrations were lower than the limit values proposed in EU legislation preparatory work for precipitated phosphate salts that could be from municipal wastewater. The tested PFCs were present in lower concentrations than in average Finnish municipal wastewater sludge.

The NPHarvest process works even if there are certain improvements that could be done. Most importantly, the pretreatment unit should be scaled up so that it would match with the membrane reactor scale. This is going to happen in 2020.

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Appendices

Appendix 1. Growth test results by Biolan. 14 pages.
Appendix 2. Terveyden ja hyvinvoinnin laitos. Testausseloste vesi 141/19. 4 pages.
Appendix 3. MetropoliLab. TESTAUSSELOSTE 2019-14303. 2 pages.
Appendix 4. Eurofins. Tutkimustodistus AR-19-RZ-021514-02. 23 pages.

Appendix 1. Growth test results by Biolan

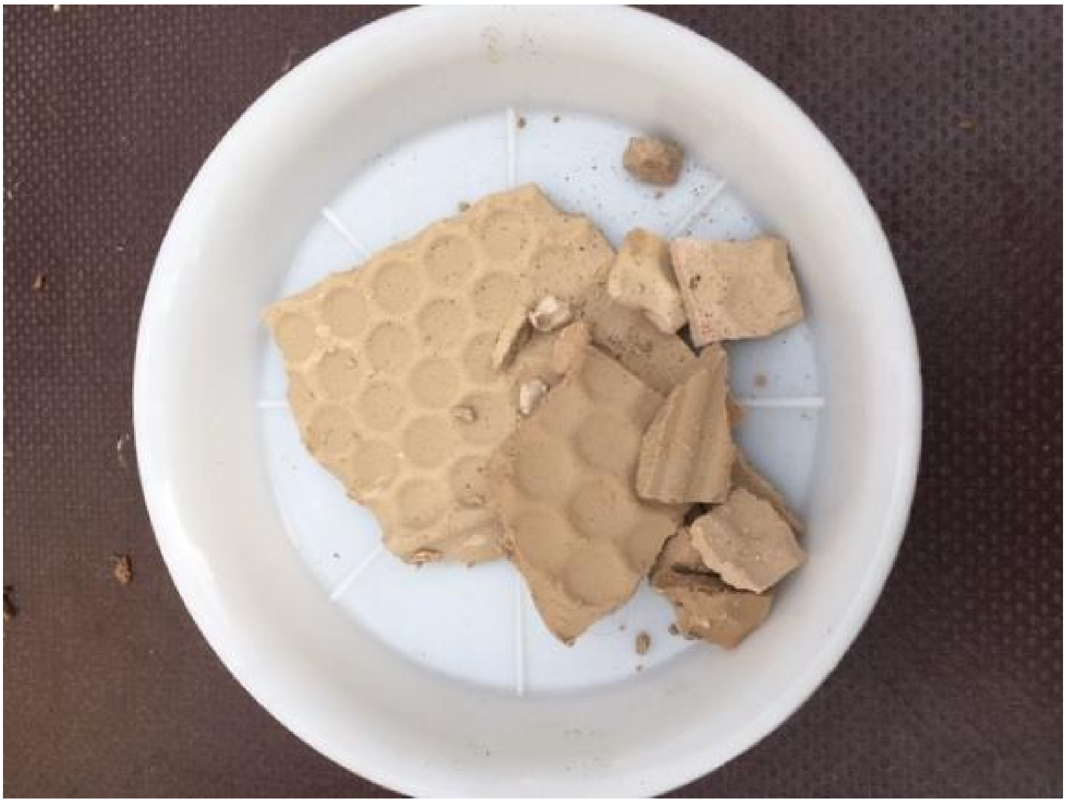
<u>Suodatettu lietekakku</u>

Koejärjestelyt:
Kokeessa käytetty turve lannoitettiin 1 g/l ja kalkittiin 6 g/l. Kokeeseen käytetty suodatuslietelevy rouhittiin ja sijoitettiin varastolannoitukseksi purkin yhdelle sivulle. Lietteen annostelu 5 ml ja 10 ml per ruukku. Verranteena käytetiin Biolanin Yrtti- ja taimilannoitetta annostelu n. 10 ml/ruukku. Kasteluun käytettiin pelkkää vettä. Koekasveina käytettiin kiinankaalia ja tomaattia. Lietekakun kosteus oli 40,4%.

Tulokset:
Kiinankaali kasvoi kohtalaisesti. Lietelannoituksella olevilla kasveilla nähtävää ravinnepuutosta (typpi). Kiinankaalin ruusukkeen painot: lietekakku 5 ml 22,6 g, lietekakku 10 ml 33,4 g ja verranne 49,2 grammaa. Typen määrää kuvaava N-arvo oli kuitenkin tasainen 5 ml 34,8; 10 ml 33,4 ja verranne 35,3. Juuret eivät hakeutuneet samalla tavalla lietteeseen kuin lannoitteeseen normaalisti, kuitenkin myös lietteessä oli jonkin verran juuria seassa.

Tomaatilla 10 ml lietettä tuotti kookkaimmat taimet, painoa oli keskimäärin 26,7g. Toiseksi painavimmat taimet olivat verranteella 22 grammaa ja 5 ml tuotti 18,3 gr. Verranne oli tummempi kuin muut, tämä näkyi myös lehtivihreän määrässä. Verranteen N-arvo oli 57,3; 5 ml N-arvo oli 48 ja 10 ml 42,6. Lietettä saaneilla näkyi typen puutosta keltaisten alalehtien muodossa. Juuristo oli hyvä kaikilla koejäsenillä.

Kuvia:



Kuva 1 Kuva kakkupaloista, jotka murennettiin kokeeseen.

Kuva 2 Kiinankaalit.

Kuva 3 Kiinankaalien juuret.

Kuva 4 Tomaatit. Vasemmalta: verranne, 5 ml, 10 ml.

Kuva 5 Tomaattien juuret.

Kuva 6 Lietekakku tomaatin juurissa.

<u>LKD-liete (lingottu liete)</u>

Koejäsenet:

	JK	pH	NO3/NO2	kost%	paino k-a	N-arvo	paino k-a	N-arvo
turve lan.	29.5	3.9	50/0					
LKD-5ml/l	36.5	5	25/0		18.7	32.4	12.1	48.4
LKD 8 ml/l	27.5	6.1	25/0		28.57	30.4	17.5	48.8
LKD-liete				61.1				

Turpeeseen lisätty 1 kg/m3 multimixiä ja 6 kg/m3 kalkkia. Huom! turpeesta jäi kalkki pois, siksi ei vderrannetta!

Tulokset:
LKD-liete toimi kalkin sijaan turpeen kalkitsemiseen kohtalaisen hyvin. Annostusta voitaisiin nostaa hieman. Tomaatilla tulos saman suuntainen, 8 ml/LKD-lietettä tuotti oikein hyvät tomaatintaimet 5 ml lietettä jätti juuriston heikommaksi.

Kuvia:

Kuva 7 Kiinankaalit.

Kuva 8 Kiinankaalien juuret.

Kuva 9 Tomaatit.

Kuva 10 Tomaattien juuret.

<u>Sammalsuodatinmateriaali</u>

Koe:
Kasvatetaan salaattia muutamalla eri pitoisuudella.

Koejäsenet:
Sammalsuodatinmateriaali; turve 50% ja sammalsuod. 50 %; turve 80% ja sammalsuod. 20 %; turve 100%. Turve kalkittu 6 kg/m3. 100% turvetta sisältää lannoitetta 1 kg/m3.

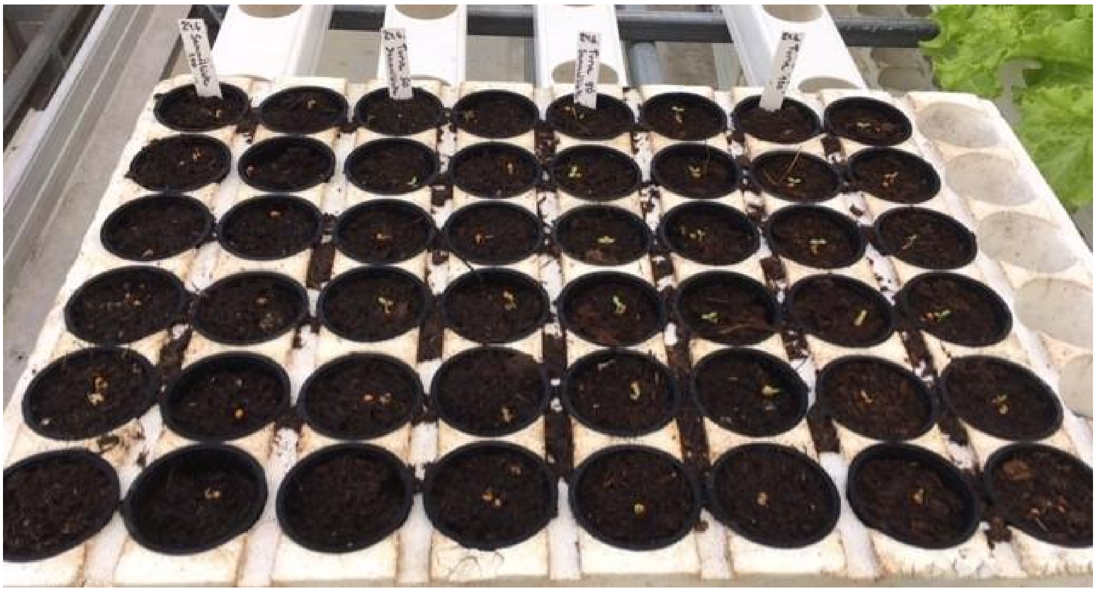
Koekasvi:
Lehtisalaatti Grand Rapids Ritsa. Kiertävä lannoitusvesi 1,8 mS/m. Veden pH 6,5. Ssa-laatit kylvetty 6 cm ruukkuihin.

Tulokset:
Kaikki salaatit kasvoivat hyvin. Pieni määrä sammallietettä tuotti suurimmat kasvit

Mittaustuloksia	Cen-L	JK	pH	NO3	NO2	kosteus
Sammalsuodatinmateriaali	397.2	27	8.5	0	0	82.1
turve 50% ja sammalsuod. 50 %		16	6.9	0	0	
turve 80% ja sammalsuod. 20 %		10	6.3	0	0	
turve 100%	110	23	5	50	0	37

PVM	Koejäsen	paino, g	1	2	3	4	5	6	Paino keski-määrin, g
27.7.	turve 100	ruukku	138.1	102.3	146.9	143.7	106.9	140	130
		lehtipaino	70.3	47.2	75.9	72.8	47.7	75.5	65
	turve 80 sam-mall. 20	ruukku	143.9	108.9	161.6	172.1	157.8	148.6	149
		lehtipaino	72.1	55.9	91.6	96.1	88.8	78.2	80
	turve 50 sam-mall. 50	ruukku	129.8	145.8	125.4	149	142.7	117.7	135
		lehtipaino	61.2	78.9	64.9	82.6	77.5	56.5	70
	sammalliete 100	ruukku	121.8	136.6	126.4	117	123	86.7	119
		lehtipaino	58.8	64.2	65.5	54.5	56.5	24.6	54

Kuvia



Kuva 11 Salaatit kokeen alussa.

Kuva 12 Salaatit noin 1,5 viikkoa kokeen aloittamisen jälkeen (8.7.). Kauimmaisesta lähimpään: turve 100 %; turve/sammalliete 80/20; turve/sammalliete 50/50; sammalliete 100 %.

Kuva 13 Salaatit noin 2 viikkoa kokeen aloittamisen jälkeen (12.7.).

Kuva 14 Salaatit kokeen lopussa (24.7.).

Kuva 15 Salaatit kokeen lopussa. Vasemmalta: turve 100 %; turve/sammalliete 80/20; turve/sammalliete 50/50; sammalliete 100 %.

Kuva 16 Salaatti lopussa, turve 100 %.

Kuva 17 Turve/sammalliete 80/20.

Kuva 18 Turve/sammalliete 50/50.

Kuva 19 Sammalliete 100 %.

<u>Ammoniumsulfaatti</u>

Koejärjestelyt:
Toisessa kasvualtaassa kurkut 2 kpl kasvavat pelkässä vedessä, kurkkulajike on Tasty Green ja kysessä on avomaankurkku. Toisessa kasvualtaassa on veteen lisätty 0,5 dl ammoniumsulfaattia 1L vettä kohden, kastelualtaan liuoksen johtokyky on noin 0,9 ja pH 3,4. Korkeampaa johtokykyä ei voi antaa, sillä pH menee liian alas

Amsulf. altaan toiselta kurkulta kärähtänyt latva viikon 30 helteillä, tuolloin annettiin myös pusseihin pelkkää vettä.

Vettä lisättiin kokeessa viisi kertaa, mittaustulokset koskee ammoniumsulfaatti säiliötä, vesikurkut saivat 10L enemmän vettä. Kasvihuoneen veden johtokyky on noin 0,4 mS/cm ja pH 7,8

PVM	määrä lit-roissa	käytetyn veden jk mS/cm	jk lisäyksen mS/cm	pH en-nen	pH jäl-keen	NO3 ennen	NO3 jäl-keen	lisätty am-monium-sulfaatti desilit-roina
27.6.	10		1		3.35			0.2
2.7.	20		0.9		3.4	25	10	1
17.7.	20	1	0.9	3.2	3.3	25	25	1
29.7.	20	1.5	0.6	3.2	3.7	25	25	1
16.8.	20							1
yht	90							4.2

Säiliön tyhjennys, vesi -28 l
Säiliön tyhjennys, amsulf. -22 l

Tulokset:
Kuukauden kasvatuksessa ei nähtävissä eroa.
Lisätty 16.8 vesikurkuille vettä 30 l. Ammoniumsulfaattia 1 dl ja 20 l vettä. Molemmat kasvaneet pituutta hyvin. Ammoniumsulfaattia saaneessa selvästi tummemmat lehdet. Molemmista kerätty kaksi kurkkua:
- vesi: 1207 g ja 798 g
- amsulf: 713 g ja 512 g

11.9. verrannekurkut käytännössä kuoleet, kärsivät pahasta typen puutteesta, ammoniumsulfaattikurkuista toinen vielä vihreähkö. Ammoniumsulfaattilannoite toimi hyvänä typenlähteenä kurkuille, happamuus ei ainakaan kurkun kohdalla ollut este kasvulle.

Ammoniumsulfaattikokeen purku 13.9.:

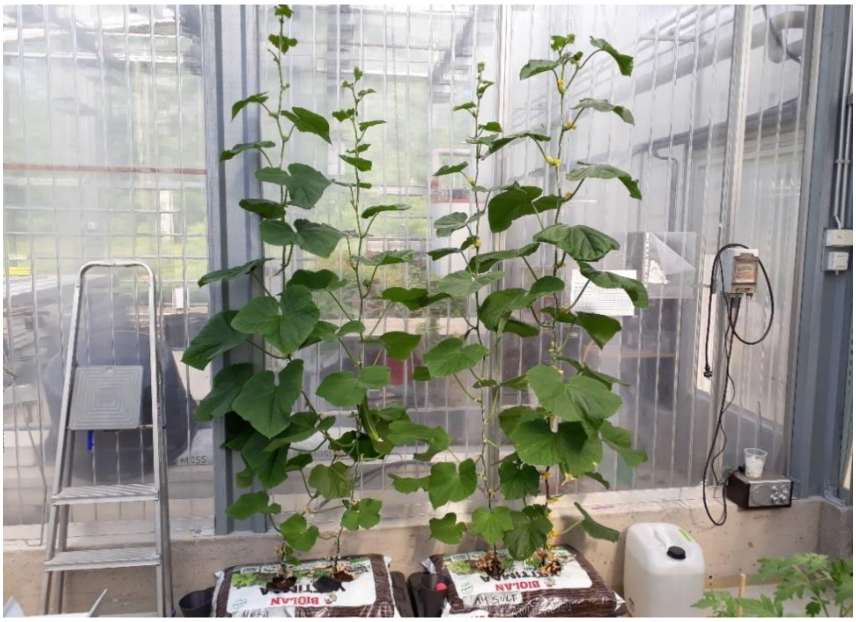
	varren pituus metreinä	lehtihangat	rungon paino grammoina
VESI	4.2	47	210
	3.5	44	140
AMM. SULF	3.6	41	235
	3.4	44	140

Kuvia:

Kuva 20 Kurkut istutettu 27.6.

Kuva 21 Kurkut 8.7.

Kuva 22 Kurkut 12.7.



Kuva 23 Kurkut 29.7.

Kuva 24 Kurkut 16.8.

Kuva 25 Kurkut 16.8.

Kuva 26 Kurkut 11.9.

Kuva 27 Ammoniumsulfaattia saaneen kurkun juuret.

Kuva 28 Vain vettä saaneen kurkun juuret.

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Irene Konola
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Näytetiedot	
Näytteet:	3 kpl jätevesi-/lietenäytteitä
Näytteenottopäivämäärä: 11.6.2019	Näytteiden vastaanottopäivämäärä: 12.6.2019
Analysointipäivät: 12.-25.6.2019	
Tehtävä: Mikrobiologiset analyysit:	- *E. coli* - Sulfiittia pelkistävät klostridit, itiöt ja vegetatiiviset solut - Salmonella spp. - Legionella, viljely ja qPCR - Somaattiset ja F-spesifiset kolifaagit

Näytetunniste	**THL:n näytetunniste**
1) Mädätyksen jälkeinen rejektivesi: nestefraktio + lietefraktio	19V1532 + 19V1533
2) Ammoniumsulfaattiliuos	19V1534
3) Nestemäinen liete (kuiva-aine 1-1,5 %, hygienisoitu)	19V1535

Menetelmäkuvaukset

E. coli
E. coli määritettiin standardin SFS-EN ISO 9308-1:2014/A1:2017 mukaisesti kromogeenisellä Chromocult Coliform Agar -kasvualustalla. Chromocult-alustalla *E. coli* kasvaa sinisinä pesäkkeinä.

Sulfiittia pelkistävät klostridit, itiöt ja vegetatiiviset solut
Sulfiittia pelkistävät klostridit analysoitiin kalvosuodatusmenetelmällä standardin SFS-EN 26461-2 mukaisesti TSC-alustalla. Itiöiden testaamista varten suodatinkalvoa lämpökäsiteltiin näytteen suodattamisen jälkeen 75 °C:ssa 15 minuutin ajan.

Salmonella
Salmonellojen toteaminen perustui standardiin ISO 19250:2010. Näytteitä esirikastettiin 36 °C 18 ± 2 h. Inkuboinnin jälkeen esirikastetta siirrostettiin selektiiviseen rikasteliemeen, jota inkuboinnin jälkeen viljeltiin erotteleville kiinteille kasvualustoille salmonellojen havaitsemiseksi.

Legionellat viljellen
Viljeltävien legionellojen pitoisuuksien selville saamiseksi näytteen tutkimusmenetelmän pohjana käytettiin standardiin ISO 11731:1998 perustuvia ja 1.7.2013 päivitettyjä THL:n YVES TO11-ohjetta (5. versio) ja YVESTO22-ohjetta (4. versio). Kyseinen ISO-standardi kumottiin vuoden 2017 lopussa, ja sen korvaavan uuden standardin SFS EN ISO 11731:2017 testausta tehdään parhaillaan THL:ssä. Bakteeripitoisuudet esitetään pmy/ml eli pesäkkeitä muodostavien yksiköiden määränä millilitraa vettä kohti laskettuna. Pienin havaittavissa oleva viljeltävien legionellojen pitoisuus oli 1 pmy/ml käsittelyssä olleiden vesitilavuuksien 1 ja 10 ml mukaan. Näytteenkäsittelyssä tehtiin laimennuksen lisäksi happopesuja ja lämpökäsittelyjä.

Legionellat geenimonistusmenetelmin (kvantitatiivinen polymeraasiketjureaktio, qPCR)
Legionellat määritettiin näytteistä eristämällä nukleiinihapot (DNA ja RNA) joko suoraan 1 ml näytetilavuudesta tai konsentroiduista näytteistä ja analysoimalla *Legionella*-suvulle spesifinen osa nukleiinihappoja kvantitatiivisella qPCR-menetelmällä. *L. pneumophila* -lajille (seroryhmät 1-15) spesifiset geenit analysoitiin pelkästään DNA-jakeesta. QPCR-menetelmillä saadut bakteeripitoisuudet esitetään GC/ml eli genomikopioiden määränä millilitraa vettä kohti laskettuna.

Kolifaagit
Somaattiset ja F-spesifiset kolifaagit määritettiin kvantitatiivisesti plakkitekniikan avulla US EPA Method 1602 mukaisesti, joko laimennossarjan avulla tai 100 ml:n tilavuudesta.

Kaikki menetelmät:

Menetelmiä ei ole akkreditoitu tutkituille näytematriiseille.

Tulokset

Tulokset on esitetty taulukoissa 1-3.

Taulukko 1. *E. coli* -bakteerin, sulfiittia pelkistävien klostridien ja salmonellan tulokset näytteissä.

THL:n näytetunniste	*E.coli*-bakteeri (pmy/ml)	Sulfiittia pelkistävät klostridit, itiöt (pmy/ml)	Sulfiittia pelkistävät klostridit, vegetatiiviset solut (pmy/ml)	Salmonella
19V1532 + 19V1533	400	4 800	18 000	todettiin/0,1 ml
19V1534	ei todettu (< 0,01)	ei todettu (< 0,01)	ei todettu (< 0,01)	ei todettu/100 ml
19V1535	ei todettu* (<1)	2 300	3 600	ei todettu/110 ml

*Tulos luotettava tasolle 0,1 ml, sen jälkeen tuloksen luotettavuutta heikentää analyysin aloittaminen 2 vrk näytteenoton jälkeen

Taulukko 2. Legionellatulokset viljellen ja qPCR:llä.

THL:n näytetunniste	Legionellat, viljely eläville (pmy/ml)	Legionella qPCR – sukutaso (Lspp, 16S) DNA (GC/ml)	Legionella qPCR – sukutaso (Lspp, 16S) RNA (GC/ml)	Legionella qPCR –*L.pneumophila* seroryhmät 1-15, DNA (GC/ml)
19V1532 + 19V1533	ei todettu (<1, alle havaitsemisrajan)***	1 800	5 200 000	havaittiin (tulos alle kvantitatiivisen rajan)
19V1534	ei todettu (<1, alle havaitsemisrajan)	ei todettu	ei todettu	ei todettu
19V1535	ei todettu (<1, alle havaitsemisrajan)	ei todettu	ei todettu	ei todettu

***tässä näytteessä legionellaviljelyssä oli paljon muuta mikrobikasvua, mikä mahdollisesti vaikeutti legionellojen havaitsemista maljoilta tai esti legionellojen kasvua maljoilla.

Taulukko 3. Somaattisten ja F-spesifisten kolifaagien tulokset näytteissä. PFU=plakin muodostava yksikkö.

THL:n näytetunniste	Somaattiset kolifaagit	F-spesifiset kolifaagit
19V1532 + 19V1533	42 PFU/ml	0,03 PFU/ml
19V1534	Ei tulosta**	Ei tulosta**
19V1535	Ei todettu/100 ml	Ei todettu/100 ml

**Analyysissä käytetty isäntäbakteeri on tuhoutunut todennäköisesti matalan pH:n vuoksi.

Tuloksen luotettavuuteen vaikuttavat asiat

Näytteiden 1) ja 3) koostumus (neste + kiinteä fraktio) sekä mahdollisesti näytteiden sisältämät analyysejä häiritsevät tekijät saattoivat heikentää analyysien toimivuutta.

Näytteen 2) matala pH saattoi heikentää analyysien toimivuutta.

Asiakirjan kokonaissivumäärä liitteineen

4

Tulosten varmentaja(t)	
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FINAS
Finnish Accreditation Service
T058 (EN ISO/IEC 17025)

Näytetiedot

Näyte otettu	11.06.2019	**Kellonaika**	11.30
Vastaanotettu	13.06.2019	**Kellonaika**	11.10
Tutkimus alkoi	13.06.2019	**Näytteenoton syy**	Tilaustutkimus
Ottopiste	Viikinmäen jätevedenpuhdistamo		
Näytteen ottaja	Tilaajan toimesta		
Viite	T21304-Gustavsson		

Näytteen 2 niin hapan (pH noin 0,5), että NO3, PO4, Ptot määritys ei onnistu näytteestä.

Analyysi		Menetelmä	14303-1 Jätevesi Rejektivesi Viikinmäen jätevedenpuhdistamo	14303-2 Erityisnäyte Ammonium sulfaatti Viikinmäen jätevedenpuhdistamo	14303-3 Liete Suodatettu liete Viikinmäen jätevedenpuhdistamo	14303-4 Liete Lingottu liete Viikinmäen jätevedenpuhdistamo	Yksikkö	Epävarmuus-%
Ammoniumtyppi, NH4-N	*	ISO 7150: 1984, DA	770	5 000			mg/l	15
Ammoniumtyppi, NH4-N, vesiliukoinen		SFS-EN 13652			61,4	620,5	mg/kg ka	20
Nitraattityppi, NO3-N	*	Sis. menet. DA	0,14				mg/l	15
Nitraattityppi, NO3-N, vesiliukoinen		SFS 3029 DA			0,4	5,3	mg/kg ka	20
Kokonaistyppi, N	*	SFS-EN ISO 11905-1	960	6 300			mg/l	15
Fosfaattifosfori, PO4-P	*	SFS-EN ISO 6878: 2004	2,9				mg/l	15
Fosfaatti, PO4-P, vesiliukoinen		SFS-EN ISO 6878:2004			< 0,1	< 0,1	mg/kg ka	20
Kokonaisfosfori, P	*	SFS 3026 mod. DA	16				mg/l	15
Kosteus	*	SFS-EN 13040:2008			44,0	59,0	%	10
Kokonaistyppi	* 1)	Kjeldahl			7	4	g/kg ka	7
Fosfori, P	*	ICP-OES: SFS-EN ISO 11885:200			720	460	mg/kg ka	25

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Analyysi		Menetelmä	14303-5 Liete Sammalsuodatettu liete Viikinmäen jätevedenpuhdistamo				Yksikkö	Epävarmuus-%
Ammoniumtyppi, NH4-N	*	ISO 7150: 1984, DA					mg/l	15
Ammoniumtyppi, NH4-N, vesiliukoinen		SFS-EN 13652	1 830,5				mg/kg ka	20
Nitraattityppi, NO3-N	*	Sis. menet. DA					mg/l	15
Nitraattityppi, NO3-N, vesiliukoinen		SFS 3029 DA	2,0				mg/kg ka	20
Kokonaistyppi, N	*	SFS-EN ISO 11905-1					mg/l	15
Fosfaattifosfori, PO4-P	*	SFS-EN ISO 6878: 2004					mg/l	15
Fosfaatti, PO4-P, vesiliukoinen		SFS-EN ISO 6878:2004	< 0,1				mg/kg ka	20
Kokonaisfosfori, P	*	SFS 3026 mod. DA					mg/l	15
Kosteus	*	SFS-EN 13040:2008	81,4				%	10
Kokonaistyppi	* 1)	Kjeldahl	9				g/kg ka	7
Fosfori, P	*	ICP-OES: SFS-EN ISO 11885:2009	470				mg/kg ka	25

* = Akkreditoitu menetelmä
1)=näytteen tutkija SeiLab Oy

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Korvaa*

Tutkimustodistus	AR-19-RZ-021514-02	Sivu 1/23
Päivämäärä	25.07.2019	
Näyte saapui	26.06.2019	
Tutkimusnro	EUAA56-00022712	
Asiakasnro	RZ0002815	
Tutkimuksen yhteyshenkilö	Johanna Vainio	

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Näytenumero			750-2019-00035329	750-2019-00035330	750-2019-00035331	750-2019-00035332	750-2019-00035333
Näytteen nimi			1. Rejektivesi	2. Ammoniumsulfaattiliuos	3. Kiinteä liete 1 (Outotec)	4. Kiinteä liete 2 (sammal)	5. Kiinteä liete 3 (sentrifugi + LKD)
Näytteen kuvaus			Jätevesi	Muu vesinäyte	Puhdistamoliete	Puhdistamoliete	Puhdistamoliete
Näytteenottoaika			25.06.2019	25.06.2019	25.06.2019	25.06.2019	25.06.2019
Kuiva-aine							
Kuiva-ainepitoisuus	RZDRY	%			56	18	
Alkuaineet, kokonaispitoisuus, HCl/HNO3, ICP-MS							
Arseeni (As)	RZ0EB	mg/l	0,014	<0,005			0,038
Boori (B)	RZ0EV	mg/l	<0,050	<0,050			<0,050
Elohopea (Hg)	RZ0EH	mg/l	0,00019	<0,00010			0,020
Kadmium (Cd)	RZ0EJ	mg/l	0,00024	<0,00020			0,0026
Kalium (K)	RZ0FJ	mg/l	82	0,97			2400
Kalsium (Ca)	RZ0F1	mg/l	96	6,6			1800
Koboltti (Co)	RZ0EK	mg/l	0,020	0,016			0,14
Kromi (Cr)	RZ0EF	mg/l	0,015	0,32			0,064
Kupari (Cu)	RZ0F2	mg/l	0,11	0,18			0,32
Lyijy (Pb)	RZ0ED	mg/l	0,0035	0,017			0,20
Magnesium (Mg)	RZ0F4	mg/l	30	0,18			20
Mangaani (Mn)	RZ0F5	mg/l	0,082	0,22			1,1
Molybdeeni (Mo)	RZ0EM	mg/l	0,025	0,19			0,016
Natrium (Na)	RZ0FL	mg/l	83	1,4			630
Nikkeli (Ni)	RZ0EN	mg/l	0,078	1,2			0,25
Rauta (Fe)	RZ0ET	mg/l	19	6,9			22
Rikki (S)	RZ0FN	mg/l	34	20000			75
Seleeni (Se)	RZ0FB	mg/l	0,0061	<0,0010			0,025
Sinkki (Zn)	RZ0FC	mg/l	0,13	1,2			0,20
Mikroaaltohajotus	RZE17		Tehty	Tehty			Tehty
Alkuaineet, kiinteä matriisi, pitoisuus kuiva-ainetta kohti, ICP-MS							
Mikroaaltohajotus	RZE18				Tehty	Tehty	
Arseeni (As)	RZ0VE	mg/kg ka			3,9	<1,0	
Boori (B)	RZ0VW	mg/kg ka			<20	<20	
Elohopea (Hg)	RZ0VL	mg/kg ka			0,35	0,10	
Kadmium (Cd)	RZ0VM	mg/kg ka			0,24	0,26	
Kalium (K)	RZ0VZ	mg/kg ka			1100	1900	
Kalsium (Ca)	RZ0W0	mg/kg ka			340000	35000	
Koboltti (Co)	RZ0VN	mg/kg ka			1,7	1,1	
Kromi (Cr)	RZ0VG	mg/kg ka			13	1,9	
Kupari (Cu)	RZ0W1	mg/kg ka			1500	12	
Lyijy (Pb)	RZ0VH	mg/kg ka			230	13	
Magnesium (Mg)	RZ0W2	mg/kg ka			6200	2100	
Mangaani (Mn)	RZ0W3	mg/kg ka			2100	160	
Molybdeeni (Mo)	RZ0VP	mg/kg ka			5,1	<2,0	
Natrium (Na)	RZ0W4	mg/kg ka			460	780	

Tutkimustodistus AR-19-RZ-021514-02

Päivämäärä 25.07.2019

Näyte saapui 26.06.2019

Näytenumero			**750-2019-00035329**	**750-2019-00035330**	**750-2019-00035331**	**750-2019-00035332**	**750-2019-00035333**
Näytteen nimi			1. Rejektivesi	2. Ammoniumsulfaattiliuos	3. Kiinteä liete 1 (Outotec)	4. Kiinteä liete 2 (sammal)	5. Kiinteä liete 3 (sentrifugi + LKD)
Näytteen kuvaus			Jätevesi	Muu vesinäyte	Puhdistamoliete	Puhdistamoliete	Puhdistamoliete
Näytteenottoaika			25.06.2019	25.06.2019	25.06.2019	25.06.2019	25.06.2019
Natrium (Na)	RZ0W4	mg/kg ka			460	780	
Nikkeli (Ni)	RZ0VI	mg/kg ka			11	3,8	
Rauta (Fe)	RZ0VT	mg/kg ka			5700	2700	
Rikki (S)	RZ0W5	mg/kg ka			3600	1300	
Seleeni (Se)	RZ0VQ	mg/kg ka			<1,0	<1,0	
Sinkki (Zn)	RZ0W6	mg/kg ka			51	43	
Lääkeaineet							
4-Asetamidoantipyrine	RZPDR	µg/l		<0,10			
4-Formyyliaminoantipyriini	RZPDR	µg/l		<0,20			
5-metyylibentsotriatsoli	RZPDR	µg/l		2,9			
Amiloridi	RZPDR	µg/l		<0,050			
Amiodaroni	RZPDR	µg/l		<0,20			
Amlodipiini	RZPDR	µg/l		<2,0			
Amoksisilliini	RZPDR	µg/l		<1,0			
Ampisilliini	RZPDR	µg/l		<0,050			
Asetanilidi	RZPDR	µg/l		<0,10			
Atenololi	RZPDR	µg/l		<0,050			
Atorvastatiini	RZPDR	µg/l		<0,10			
Atsatiopriini	RZPDR	µg/l		<0,050			
Atsitromysiini	RZPDR	µg/l		<0,10			
Beklometasoni	RZPDR	µg/l		<0,050			
Bendroflumetiatsidi	RZPDR	µg/l		<0,10			
Bentsotriatsoli	RZPDR	µg/l		0,81			
Betsafibraatti	RZPDR	µg/l		<0,050			
Bisoprololi (ß-Adrenergics)	RZPDR	µg/l		<0,10			
Bromokriptiini	RZPDR	µg/l		<0,050			
Budesonidi	RZPDR	µg/l		<0,10			
Buspironi	RZPDR	µg/l		<0,050			
Dapsoni	RZPDR	µg/l		<0,10			
Desloratadiini	RZPDR	µg/l		<0,050			
Diatritsoaatti (Amidotritsoaatti)	RZPDR	µg/l		<0,20			
Diklofenaakki	RZPDR	µg/l		<0,050			
Doksisykliini	RZPDR	µg/l		<0,20			
Enalapriili	RZPDR	µg/l		<0,10			
Enrofloksasiini	RZPDR	µg/l		<0,20			
Entakaponi	RZPDR	µg/l		<0,10			
Erytromysiini	RZPDR	µg/l		<2,5			
Febanteeli	RZPDR	µg/l		<0,050			
Felodipiini	RZPDR	µg/l		<0,50			
Fenatsoni	RZPDR	µg/l		<0,050			
Fenbendatsoli	RZPDR	µg/l		<0,050			
Flubendatsoli	RZPDR	µg/l		<0,050			
Fluoksetiini	RZPDR	µg/l		<0,10			
Flutamidi	RZPDR	µg/l		<0,050			
Fluvastatiini	RZPDR	µg/l		<0,10			
Fluvoksamiini	RZPDR	µg/l		<0,050			
Furosemidi	RZPDR	µg/l		<0,50			
Gemifibrotsiili	RZPDR	µg/l		<0,10			
Glyburidi (Glibenklamidi)	RZPDR	µg/l		<0,10			
Hydroklooritiatsidi	RZPDR	µg/l		<0,50			
Hydrokortisoni	RZPDR	µg/l		<0,10			

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Näytenumero			750-2019-00035329	750-2019-00035330	750-2019-00035331	750-2019-00035332	750-2019-00035333
Näytteen nimi			1. Rejektivesi	2. Ammoniumsulfaattiliuos	3. Kiinteä liete 1 (Outotec)	4. Kiinteä liete 2 (sammal)	5. Kiinteä liete 3 (sentrifugi + LKD)
Näytteen kuvaus			Jätevesi	Muu vesinäyte	Puhdistamoliete	Puhdistamoliete	Puhdistamoliete
Näytteenottoaika			25.06.2019	25.06.2019	25.06.2019	25.06.2019	25.06.2019
Hydrokortisoni	RZPDR	µg/l		<0,10			
Ibuprofeeni	RZPDR	µg/l		<5,0			
Ifosfamidi	RZPDR	µg/l		<0,20			
Iopamidoli	RZPDR	µg/l		<0,20			
Iopromidi	RZPDR	µg/l		<0,20			
Ipratropium	RZPDR	µg/l		<0,050			
Ivermektiini	RZPDR	µg/l		<0,10			
Karbamatsepiini	RZPDR	µg/l		<0,050			
Karvediloli	RZPDR	µg/l		<0,050			
Ketiapiini	RZPDR	µg/l		<0,050			
Ketokonatsoli	RZPDR	µg/l		<0,10			
Ketoprofeeni	RZPDR	µg/l		<0,050			
Klaritromysiini	RZPDR	µg/l		<0,10			
Klenbuteroli	RZPDR	µg/l		<0,050			
Klofibrihappo	RZPDR	µg/l		<0,50			
Kloksasilliini	RZPDR	µg/l		<0,050			
Klotsapiini	RZPDR	µg/l		<0,050			
Kofeiini	RZPDR	µg/l		0,95			
Ksylometatsoliini	RZPDR	µg/l		<0,010			
Lamotrigiini	RZPDR	µg/l		<0,050			
Loratadiini	RZPDR	µg/l		<0,050			
Losartaani	RZPDR	µg/l		<0,050			
Meropeneemi	RZPDR	µg/l		<0,50			
Metoprololi	RZPDR	µg/l		<0,050			
Metotreksaatti	RZPDR	µg/l		<0,10			
Metronidatsoli	RZPDR	µg/l		<0,20			
Metyyliprednisoloni	RZPDR	µg/l		<0,10			
Mianseriini	RZPDR	µg/l		<0,050			
Mirtatsapiini	RZPDR	µg/l		<0,050			
Mometasonifuroaatti	RZPDR	µg/l		<0,20			
N4-Asetyylisulfametoksatsoli	RZPDR	µg/l		<0,050			
Naprokseeni	RZPDR	µg/l		<0,10			
N-Demetyylierytromysiini A	RZPDR	µg/l		<2,0			
Nelfinaviiri	RZPDR	µg/l		<0,050			
Nitenpyram	RZPDR	µg/l		<0,10			
Norfloksasiini	RZPDR	µg/l		<0,50			
Ofloksasiini	RZPDR	µg/l		<0,50			
Oksitetrasykliini	RZPDR	µg/l		<0,50			
Oksymetatsoli	RZPDR	µg/l		<0,050			
Parasetamoli	RZPDR	µg/l		<0,50			
Paroksetiini	RZPDR	µg/l		<0,050			
Penisilliini G -bentsatiini	RZPDR	µg/l		<5,0			
Piperasilliini	RZPDR	µg/l		<0,10			
Pratsikvanteli	RZPDR	µg/l		<0,050			
Primidoni	RZPDR	µg/l		<0,050			
Propafenoni	RZPDR	µg/l		<0,050			
Propanololi	RZPDR	µg/l		<0,10			
Propyfenatsoni	RZPDR	µg/l		<0,050			
Pyranteeli	RZPDR	µg/l		<0,10			
Raloksifeeni	RZPDR	µg/l		<0,050			
Ramipriili	RZPDR	µg/l		<0,050			

Näytenumero			**750-2019-00035329**	**750-2019-00035330**	**750-2019-00035331**	**750-2019-00035332**	**750-2019-00035333**
Näytteen nimi			1. Rejektivesi	2. Ammoniumsulfaattiliuos	3. Kiinteä liete 1 (Outotec)	4. Kiinteä liete 2 (sammal)	5. Kiinteä liete 3 (sentrifugi + LKD)
Näytteen kuvaus			Jätevesi	Muu vesinäyte	Puhdistamoliete	Puhdistamoliete	Puhdistamoliete
Näytteenottoaika			25.06.2019	25.06.2019	25.06.2019	25.06.2019	25.06.2019
Risperidoni	RZPDR	µg/l		<0,050			
Roksitromysiini	RZPDR	µg/l		<0,050			
Salbutamoli (albuteroli)	RZPDR	µg/l		<0,10			
Salmeteroli	RZPDR	µg/l		<0,050			
Sertraliini ja norsertraliini	RZPDR	µg/l		0,13			
Setiritsiini	RZPDR	µg/l		<0,050			
Simvastatiini	RZPDR	µg/l		<5,0			
Siprofloksasiini	RZPDR	µg/l		<0,50			
Sitalopraami	RZPDR	µg/l		<0,10			
Sotaloli	RZPDR	µg/l		<0,10			
Sulfadiatsiini	RZPDR	µg/l		<0,10			
Sulfadimidiini (Sulfametatsiini)	RZPDR	µg/l		<0,10			
Sulfadoksiini	RZPDR	µg/l		<0,10			
Sulfaguanidiini	RZPDR	µg/l		<0,50			
Sulfameratsiini	RZPDR	µg/l		<0,10			
Sulfametitsoli	RZPDR	µg/l		<0,10			
Sulfametoksatsoli	RZPDR	µg/l		<0,10			
Sulfatiatsoli	RZPDR	µg/l		<0,10			
Syklofosfamidi	RZPDR	µg/l		<0,050			
Tamoksifeeni	RZPDR	µg/l		<0,050			
Terbutaliini	RZPDR	µg/l		<0,10			
Tetrasykliini	RZPDR	µg/l		<0,10			
Toremifeeni	RZPDR	µg/l		<0,050			
Tramadoli	RZPDR	µg/l		<0,050			
Triklokarbaani	RZPDR	µg/l		<0,40			
Trimetoprim	RZPDR	µg/l		<0,010			
Tylosiini	RZPDR	µg/l		<0,20			
Varfariini	RZPDR	µg/l		<0,050			
Venlafaksiini	RZPDR	µg/l		<0,050			
Verapamiili	RZPDR	µg/l		<0,050			
4-Asetamidoantipyrine	RZ1T3	µg/l	<1,0	<0,10			
4-Formyyliaminoantipyriini	RZ1TB	µg/l	<2,0	<0,20			
5-metyylibentsotriatsoli	RZ1T4	µg/l	<1,0	2,9			
Amiloridi	RZ1S7	µg/l	<0,50	<0,050			
Amiodaroni	RZ1TC	µg/l	<2,0	<0,20			
Amlodipiini	RZ1S4	µg/l	<20	<2,0			
Amoksisilliini	RZ1TI	µg/l	<10	<1,0			
Ampisilliini	RZ1RG	µg/l	<0,50	<0,050			
Asetanilidi	RZ1T5	µg/l	<1,0	<0,10			
Atenololi	RZ1QH	µg/l	<0,50	<0,050			
Atorvastatiini	RZ1RY	µg/l	<1,0	<0,10			
Atsatiopriini	RZ1S8	µg/l	<0,50	<0,050			
Atsitromysiini	RZ1T6	µg/l	<1,0	<0,10			
Beklometasoni	RZ1QI	µg/l	<0,50	<0,050			
Bendroflumetiatsidi	RZ1RZ	µg/l	<1,0	<0,10			
Bentsotriatsoli	RZ1RE	µg/l	<4,0	0,81			
Betsafibraatti	RZ1Q4	µg/l	<0,50	<0,050			
Bisoprololi (ß-Adrenergics)	RZ1QY	µg/l	<1,0	<0,10			
Bromokriptiini	RZ1RN	µg/l	<0,50	<0,050			
Budesonidi	RZ1S0	µg/l	<1,0	<0,10			

Näytenumero			750-2019-00035329	750-2019-00035330	750-2019-00035331	750-2019-00035332	750-2019-00035333
Näytteen nimi			1. Rejektivesi	2. Ammoniumsulfaattiliuos	3. Kiinteä liete 1 (Outotec)	4. Kiinteä liete 2 (sammal)	5. Kiinteä liete 3 (sentrifugi + LKD)
Näytteen kuvaus			Jätevesi	Muu vesinäyte	Puhdistamoliete	Puhdistamoliete	Puhdistamoliete
Näytteenottoaika			25.06.2019	25.06.2019	25.06.2019	25.06.2019	25.06.2019
Budesonidi	RZ1S0	µg/l	<1,0	<0,10			
Buspironi	RZ1S9	µg/l	<0,50	<0,050			
Dapsoni	RZ1RH	µg/l	<1,0	<0,10			
Desloratadiini	RZ1RP	µg/l	<0,50	<0,050			
Diatritsoaatti (Amidotritsoaatti)	RZ1TD	µg/l	<2,0	<0,20			
Diklofenaakki	RZ1Q5	µg/l	1,4	<0,050			
Doksisykliini	RZ1PZ	µg/l	<2,0	<0,20			
Enalapriili	RZ1QL	µg/l	<1,0	<0,10			
Enrofloksasiini	RZ1RK	µg/l	<2,0	<0,20			
Entakaponi	RZ1QZ	µg/l	<1,0	<0,10			
Erytromysiini	RZ1S5	µg/l	<25	<2,5			
Febanteeli	RZ1SA	µg/l	<0,50	<0,050			
Fenatsoni	RZ1RQ	µg/l	<0,50	<0,050			
Fenbendatsoli	RZ1QU	µg/l	<0,50	<0,050			
Flubendatsoli	RZ1QV	µg/l	<0,50	<0,050			
Fluoksetiini	RZ1QM	µg/l	<1,0	<0,10			
Flutamidi	RZ1SB	µg/l	<0,50	<0,050			
Fluvastatiini	RZ1T7	µg/l	<1,0	<0,10			
Fluvoksamiini	RZ1RR	µg/l	<0,50	<0,050			
Furosemidi	RZ1S3	µg/l	<5,0	<0,50			
Gemifibrotsiili	RZ1QN	µg/l	<1,0	<0,10			
Glyburidi (Glibenklamidi)	RZ1S1	µg/l	<1,0	<0,10			
Hydroklooritiatsidi	RZ1QS	µg/l	<5,0	<0,50			
Hydrokortisoni	RZ1QP	µg/l	<1,0	<0,10			
Ibuprofeeni	RZ1QE	µg/l	<10	<5,0			
Iopamidoli	RZ1R3	µg/l	<2,0	<0,20			
Iopromidi	RZ1R4	µg/l	<2,0	<0,20			
Ipratropium	RZ1SC	µg/l	<0,50	<0,050			
Ivermektiini	RZ1Q8	µg/l	<1,0	<0,10			
Karbamatsepiini	RZ1Q6	µg/l	0,77	<0,050			
Karvediloli	RZ1SD	µg/l	<0,50	<0,050			
Ketiapiini	RZ1SE	µg/l	<0,50	<0,050			
Ketokonatsoli	RZ1RS	µg/l	<1,0	<0,10			
Ketoprofeeni	RZ1Q7	µg/l	<0,50	<0,050			
Klaritromysiini	RZ1R7	µg/l	<1,0	<0,10			
Klenbuteroli	RZ1PY	µg/l	<0,50	<0,050			
Klofibrihappo	RZ1QF	µg/l	<5,0	<0,50			
Kloksasilliini	RZ1R9	µg/l	<0,50	<0,050			
Klotsapiini	RZ1RT	µg/l	1,1	<0,050			
Kofeiini	RZ1Q1	µg/l	3,2	0,95			
Ksylometatsoliini	RZ1S6	µg/l	<0,10	<0,010			
Lamotrigiini	RZ1SF	µg/l	4,4	<0,050			
Loratadiini	RZ1RU	µg/l	<0,50	<0,050			
Losartaani	RZ1SG	µg/l	5,4	<0,050			
Meropeneemi	RZ1TH	µg/l	<5,0	<0,50			
Metoprololi	RZ1QW	µg/l	0,53	<0,050			
Metotreksaatti	RZ1R0	µg/l	<1,0	<0,10			
Metronidatsoli	RZ1R5	µg/l	<2,0	<0,20			
Metyyliprednisoloni	RZ1R1	µg/l	<1,0	<0,10			
Mianseriini	RZ1SH	µg/l	<0,50	<0,050			
Mirtatsapiini	RZ1SI	µg/l	<0,50	<0,050			
Mometasonifuroaatti	RZ1TE	µg/l	<2,0	<0,20			

Näytenumero			750-2019-00035329	750-2019-00035330	750-2019-00035331	750-2019-00035332	750-2019-00035333
Näytteen nimi			1. Rejektivesi	2. Ammoniumsulfaattiliuos	3. Kiinteä liete 1 (Outotec)	4. Kiinteä liete 2 (sammal)	5. Kiinteä liete 3 (sentrifugi + LKD)
Näytteen kuvaus			Jätevesi	Muu vesinäyte	Puhdistamoliete	Puhdistamoliete	Puhdistamoliete
Näytteenottoaika			25.06.2019	25.06.2019	25.06.2019	25.06.2019	25.06.2019
Mometasonifuroaatti	RZ1TE	µg/l	<2,0	<0,20			
N4-Asetyylisulfametoksatsoli	RZ1SJ	µg/l	<0,50	<0,050			
Naprokseeni	RZ1Q9	µg/l	<1,0	<0,10			
N-Demetyylierytromysiini A	RZ1TJ	µg/l	<20	<2,0			
Nelfinaviiri	RZ1SK	µg/l	<0,50	<0,050			
Nitenpyram	RZ1T8	µg/l	<1,0	<0,10			
Norfloksasiini	RZ1RL	µg/l	<5,0	<0,50			
Ofloksasiini	RZ1RF	µg/l	<5,0	<0,50			
Oksymetatsoli	RZ1SL	µg/l	<0,50	<0,050			
Oksitetrasykliini	RZ1QG	µg/l	<5,0	<0,50			
Parasetamoli	RZ1TF	µg/l	<5,0	<0,50			
Paroksetiini	RZ1QJ	µg/l	<0,50	<0,050			
Penisilliini G -bentsatiini	RZ1TK	µg/l	<50	<5,0			
Piperasilliini	RZ1T9	µg/l	<1,0	<0,10			
Pratsikvanteli	RZ1SM	µg/l	<0,50	<0,050			
Primidoni	RZ1SN	µg/l	<0,50	<0,050			
Propafenoni	RZ1SP	µg/l	<0,50	<0,050			
Propanololi	RZ1SQ	µg/l	<1,0	<0,10			
Propyfenatsoni	RZ1RV	µg/l	<0,50	<0,050			
Pyranteeli	RZ1TA	µg/l	<1,0	<0,10			
Raloksifeeni	RZ1SS	µg/l	<0,50	<0,050			
Ramipriili	RZ1ST	µg/l	<0,50	<0,050			
Risperidoni	RZ1SU	µg/l	<0,50	<0,050			
Roksitromysiini	RZ1SV	µg/l	<0,50	<0,050			
Salbutamoli (albuteroli)	RZ1QA	µg/l	<1,0	<0,10			
Salmeteroli	RZ1SW	µg/l	<0,50	<0,050			
Sertraliini ja norsertraliini	RZ1SR	µg/l	0,72	0,13			
Setiritsiini	RZ1RW	µg/l	4,7	<0,050			
Simvastatiini	RZ1QT	µg/l	<50	<5,0			
Siprofloksasiini	RZ1RM	µg/l	<5,0	<0,50			
Sitalopraami	RZ1QQ	µg/l	<1,0	<0,10			
Sotaloli	RZ1R2	µg/l	<1,0	<0,10			
Sulfadiatsiini	RZ1RA	µg/l	<1,0	<0,10			
Sulfadimidiini (Sulfametatsiini)	RZ1RI	µg/l	<1,0	<0,10			
Sulfadoksiini	RZ1RB	µg/l	<1,0	<0,10			
Sulfaguanidiini	RZ1R8	µg/l	<5,0	<0,50			
Sulfameratsiini	RZ1RC	µg/l	<1,0	<0,10			
Sulfametitsoli	RZ1RJ	µg/l	<1,0	<0,10			
Sulfametoksatsoli	RZ1QB	µg/l	<1,0	<0,10			
Sulfatiatsoli	RZ1RD	µg/l	<1,0	<0,10			
Syklofosfamidi	RZ1QK	µg/l	<0,50	<0,050			
Tamoksifeeni	RZ1SY	µg/l	<0,50	<0,050			
Terbutaliini	RZ1Q2	µg/l	<1,0	<0,10			
Tetrasykliini	RZ1QC	µg/l	<1,0	<0,10			
Toremifeeni	RZ1SZ	µg/l	<0,50	<0,050			
Tramadoli	RZ1T0	µg/l	<0,50	<0,050			
Triklokarbaani	RZ1TG	µg/l	<4,0	<0,40			
Trimetoprim	RZ1Q3	µg/l	<0,10	<0,010			
Varfariini	RZ1Q0	µg/l	<0,50	<0,050			
Venlafaksiini	RZ1T1	µg/l	<0,50	<0,050			

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Näytenumero			**750-2019-00035329**	**750-2019-00035330**	**750-2019-00035331**	**750-2019-00035332**	**750-2019-00035333**
Näytteen nimi			1. Rejektivesi	2. Ammoniumsulfaattiliuos	3. Kiinteä liete 1 (Outotec)	4. Kiinteä liete 2 (sammal)	5. Kiinteä liete 3 (sentrifugi + LKD)
Näytteen kuvaus			Jätevesi	Muu vesinäyte	Puhdistamoliete	Puhdistamoliete	Puhdistamoliete
Näytteenottoaika			25.06.2019	25.06.2019	25.06.2019	25.06.2019	25.06.2019
Venlafaksiini	RZ1T1	µg/l	<0,50	<0,050			
Verapamiili	RZ1T2	µg/l	<0,50	<0,050			
PAH EPA 16 yhdisteet							
Asenafteeni	RZP01	µg/l	0,050	<0,005			
Asenaftyleeni	RZP01	µg/l	<0,050	<0,005			
Antraseeni	RZP01	µg/l	<0,050	<0,005			
Bentso(a)antraseeni	RZP01	µg/l	0,050	<0,001			
Bentso(b/j)fluoranteeni	RZP01	µg/l	0,061	<0,001			
Bentso(k)fluoranteeni	RZP01	µg/l	0,014	<0,001			
Bentso(a)pyreeni	RZP01	µg/l	0,025	<0,00017			
Bentso(g,h,i)peryleeni	RZP01	µg/l	0,034	<0,0005			
Dibentso(a,h)antraseeni	RZP01	µg/l	0,006	<0,0005			
Fenantreeni	RZP01	µg/l	0,22	0,007			
Fluoreeni	RZP01	µg/l	0,059	<0,005			
Fluoranteeni	RZP01	µg/l	0,15	<0,005			
Kryseeni	RZP01	µg/l	0,045	<0,001			
Indeno(1,2,3-cd)pyreeni	RZP01	µg/l	0,013	<0,0005			
Naftaleeni	RZP01	µg/l	0,14	<0,01			
Pyreeni	RZP01	µg/l	0,15	<0,005			
Perfluoratut yhdisteet (PFC)							
Perfluorobutaanihappo (PFBA)	RZPFC	µg/l	<0,025	<0,005			
Perfluoropentaanihappo (PFPeA)	RZPFC	µg/l	<0,025	<0,005			
Perfluoroheksaanihappo (PFHxA)	RZPFC	µg/l	<0,050	<0,005			
Perfluoroheptaanihappo (PFHpA)	RZPFC	µg/l	<0,005	<0,005			
Perfluoro-oktaanihappo (PFOA)	RZPFC	µg/l	0,0080	<0,005			
Perfluorinonaanihappo (PFNA)	RZPFC	µg/l	<0,005	<0,005			
Perfluorodekaanihappo (PFDA)	RZPFC	µg/l	<0,005	<0,005			
Perfluoroundekaanihappo (PFUnA)	RZPFC	µg/l	<0,050	<0,005			
Perfluorododekaanihappo (PFDoA)	RZPFC	µg/l	<0,005	<0,005			
Perfluorotridekaanihappo (PFTrDA)	RZPFC	µg/l	<0,050	<0,005			
Perfluorotetradekaanihappo (PFTA)	RZPFC	µg/l	<0,050	<0,050			
Perfluoroheksadekaanihappo (PFHxDA)	RZPFC	µg/l	<0,050	<0,050			
Perfluoro-oktaanidekaanihappo (PFODA)	RZPFC	µg/l	<0,050	<0,050			
Perfluorobutaanisulfonaatti (PFBS)	RZPFC	µg/l	<0,005	<0,005			
Perfluoropentaanisulfonaatti (PFPeS)	RZPFC	µg/l	<0,005	<0,005			
Perfluoroheksaanisulfonaatti (PFHxS)	RZPFC	µg/l	<0,005	<0,005			
Perfluoroheptaanisulfonaatti (PFHpS)	RZPFC	µg/l	<0,005	<0,005			
Perfluoro-oktaanisulfonaatti (PFOS)	RZPFC	µg/l	0,021	<0,001			
Perfluorononaanisulfonaatti (PFNS)	RZPFC	µg/l	<0,005	<0,005			

Näytenumero			**750-2019-00035329**	**750-2019-00035330**	**750-2019-00035331**	**750-2019-00035332**	**750-2019-00035333**
Näytteen nimi			1. Rejektivesi	2. Ammoniumsulfaattiliuos	3. Kiinteä liete 1 (Outotec)	4. Kiinteä liete 2 (sammal)	5. Kiinteä liete 3 (sentrifugi + LKD)
Näytteen kuvaus			Jätevesi	Muu vesinäyte	Puhdistamoliete	Puhdistamoliete	Puhdistamoliete
Näytteenottoaika			25.06.2019	25.06.2019	25.06.2019	25.06.2019	25.06.2019
Perfluorodekaanisulfonaatti (PFDS)	RZPFC	µg/l	<0,005	<0,005			
Perfluorododekaanisulfonaatti (PFDoS)	RZPFC	µg/l	<0,005	<0,005			
1H,1H,2H,2H-Perfluoroheksanesulfonaatti (4:2 FTS)	RZPFC	µg/l	<0,005	<0,005			
1H,1H,2H,2H-Perfluoro-oktaanisulfonaatti (6:2 FTS)	RZPFC	µg/l	0,015	<0,005			
1H,1H,2H,2H-Perfluorodekaanisulfonaatti (8:2 FTS)	RZPFC	µg/l	<0,005	<0,005			

Näytenumero			**750-2019-00035334**
Näytteen nimi			6. Märkä liete
Näytteen kuvaus			Puhdistamoliete
Näytteenottoaika			25.06.2019
Lääkeaineet			
4-Asetamidoantipyrine	RZ1T3	µg/l	<0,10
4-Formyyliaminoantipyriini	RZ1TB	µg/l	<0,20
5-metyylibentsotriatsoli	RZ1T4	µg/l	6,6
Amiloridi	RZ1S7	µg/l	<0,050
Amiodaroni	RZ1TC	µg/l	<0,20
Amlodipiini	RZ1S4	µg/l	<2,0
Amoksisilliini	RZ1TI	µg/l	<1,0
Ampisilliini	RZ1RG	µg/l	<0,050
Asetanilidi	RZ1T5	µg/l	<0,50
Atenololi	RZ1QH	µg/l	<0,25
Atorvastatiini	RZ1RY	µg/l	0,59
Atsatiopriini	RZ1S8	µg/l	<0,050
Atsitromysiini	RZ1T6	µg/l	<0,50
Beklometasoni	RZ1QI	µg/l	<0,050
Bendroflumetiatsidi	RZ1RZ	µg/l	<0,10
Bentsotriatsoli	RZ1RE	µg/l	2,4
Betsafibraatti	RZ1Q4	µg/l	<0,050
Bisoprololi (ß-Adrenergics)	RZ1QY	µg/l	0,43
Bromokriptiini	RZ1RN	µg/l	<0,050
Budesonidi	RZ1S0	µg/l	<0,10
Buspironi	RZ1S9	µg/l	<0,050
Dapsoni	RZ1RH	µg/l	<0,10
Desloratadiini	RZ1RP	µg/l	0,13
Diatritsoaatti (Amidotritsoaatti)	RZ1TD	µg/l	<0,50
Diklofenaakki	RZ1Q5	µg/l	1,3
Doksisykliini	RZ1PZ	µg/l	<0,20
Enalapriili	RZ1QL	µg/l	<0,10
Enrofloksasiini	RZ1RK	µg/l	<0,20
Entakaponi	RZ1QZ	µg/l	<0,10
Erytromysiini	RZ1S5	µg/l	<2,5
Febanteeli	RZ1SA	µg/l	<0,050
Fenatsoni	RZ1RQ	µg/l	0,072
Fenbendatsoli	RZ1QU	µg/l	<0,25
Flubendatsoli	RZ1QV	µg/l	<0,050

Näytenumero			**750-2019-00035334**
Näytteen nimi			6. Märkä liete
Näytteen kuvaus			Puhdistamoliete
Näytteenottoaika			25.06.2019
Flubendatsoli	RZ1QV	µg/l	<0,050
Fluoksetiini	RZ1QM	µg/l	<0,50
Flutamidi	RZ1SB	µg/l	<0,050
Fluvastatiini	RZ1T7	µg/l	<0,10
Fluvoksamiini	RZ1RR	µg/l	<0,050
Furosemidi	RZ1S3	µg/l	<2,5
Gemifibrotsiili	RZ1QN	µg/l	<0,50
Glyburidi (Glibenklamidi)	RZ1S1	µg/l	<0,10
Hydroklooritiatsidi	RZ1QS	µg/l	<2,5
Hydrokortisoni	RZ1QP	µg/l	1,0
Ibuprofeeni	RZ1QE	µg/l	12
Iopamidoli	RZ1R3	µg/l	<0,20
Iopromidi	RZ1R4	µg/l	<0,20
Ipratropium	RZ1SC	µg/l	<0,050
Ivermektiini	RZ1Q8	µg/l	<0,10
Karbamatsepiini	RZ1Q6	µg/l	0,60
Karvediloli	RZ1SD	µg/l	<0,050
Ketiapiini	RZ1SE	µg/l	0,24
Ketokonatsoli	RZ1RS	µg/l	0,14
Ketoprofeeni	RZ1Q7	µg/l	<0,25
Klaritromysiini	RZ1R7	µg/l	<0,10
Klenbuteroli	RZ1PY	µg/l	<0,050
Klofibrihappo	RZ1QF	µg/l	<0,50
Kloksasilliini	RZ1R9	µg/l	<0,050
Klotsapiini	RZ1RT	µg/l	1,1
Kofeiini	RZ1Q1	µg/l	5,3
Ksylometatsoliini	RZ1S6	µg/l	<0,050
Lamotrigiini	RZ1SF	µg/l	3,0
Loratadiini	RZ1RU	µg/l	<0,050
Losartaani	RZ1SG	µg/l	3,7
Meropeneemi	RZ1TH	µg/l	<0,50
Metoprololi	RZ1QW	µg/l	0,56
Metotreksaatti	RZ1R0	µg/l	<0,10
Metronidatsoli	RZ1R5	µg/l	<0,20
Metyyliprednisoloni	RZ1R1	µg/l	<0,50
Mianseriini	RZ1SH	µg/l	<0,050
Mirtatsapiini	RZ1SI	µg/l	0,15
Mometasonifuroaatti	RZ1TE	µg/l	<0,20
N4-Asetyylisulfametoksatsoli	RZ1SJ	µg/l	<0,050
Naprokseeni	RZ1Q9	µg/l	<0,50
N-Demetyylierytromysiini A	RZ1TJ	µg/l	<2,0
Nelfinaviiri	RZ1SK	µg/l	<0,050
Nitenpyram	RZ1T8	µg/l	<0,10
Norfloksasiini	RZ1RL	µg/l	<0,50
Ofloksasiini	RZ1RF	µg/l	<0,50
Oksymetatsoli	RZ1SL	µg/l	<0,050
Oksitetrasykliini	RZ1QG	µg/l	<0,50
Parasetamoli	RZ1TF	µg/l	<2,5
Paroksetiini	RZ1QJ	µg/l	<0,050
Penisilliini G -bentsatiini	RZ1TK	µg/l	<5,0
Piperasilliini	RZ1T9	µg/l	<0,10
Pratsikvanteli	RZ1SM	µg/l	<0,050
Primidoni	RZ1SN	µg/l	<0,050

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Näytenumero			**750-2019-00035334**
Näytteen nimi			6. Märkä liete
Näytteen kuvaus			Puhdistamoliete
Näytteenottoaika			25.06.2019
Primidoni	RZ1SN	µg/l	<0,050
Propafenoni	RZ1SP	µg/l	<0,050
Propanololi	RZ1SQ	µg/l	0,13
Propyfenatsoni	RZ1RV	µg/l	<0,050
Pyranteeli	RZ1TA	µg/l	<0,10
Raloksifeeni	RZ1SS	µg/l	<0,050
Ramipriili	RZ1ST	µg/l	<0,050
Risperidoni	RZ1SU	µg/l	<0,050
Roksitromysiini	RZ1SV	µg/l	<0,050
Salbutamoli (albuteroli)	RZ1QA	µg/l	<0,10
Salmeteroli	RZ1SW	µg/l	<0,050
Sertraliini ja norsertraliini	RZ1SR	µg/l	0,39
Setiritsiini	RZ1RW	µg/l	4,1
Simvastatiini	RZ1QT	µg/l	<5,0
Siprofloksasiini	RZ1RM	µg/l	<0,50
Sitalopraami	RZ1QQ	µg/l	0,18
Sotaloli	RZ1R2	µg/l	<0,50
Sulfadiatsiini	RZ1RA	µg/l	<0,50
Sulfadimidiini (Sulfametatsiini)	RZ1RI	µg/l	<0,10
Sulfadoksiini	RZ1RB	µg/l	<0,10
Sulfaguanidiini	RZ1R8	µg/l	<0,50
Sulfameratsiini	RZ1RC	µg/l	<0,10
Sulfametitsoli	RZ1RJ	µg/l	<0,10
Sulfametoksatsoli	RZ1QB	µg/l	<0,10
Sulfatiatsoli	RZ1RD	µg/l	<0,10
Syklofosfamidi	RZ1QK	µg/l	<0,050
Tamoksifeeni	RZ1SY	µg/l	<0,050
Terbutaliini	RZ1Q2	µg/l	<0,10
Tetrasykliini	RZ1QC	µg/l	<0,50
Toremifeeni	RZ1SZ	µg/l	<0,050
Tramadoli	RZ1T0	µg/l	<0,25
Triklokarbaani	RZ1TG	µg/l	<0,40
Trimetoprim	RZ1Q3	µg/l	<0,010
Varfariini	RZ1Q0	µg/l	<0,050
Venlafaksiini	RZ1T1	µg/l	<0,25
Verapamiili	RZ1T2	µg/l	0,067
PAH EPA 16 yhdisteet			
Asenafteeni	RZP01	µg/l	0,067
Asenaftyleeni	RZP01	µg/l	<0,050
Antraseeni	RZP01	µg/l	0,063
Bentso(a)antraseeni	RZP01	µg/l	0,070
Bentso(b/j)fluoranteeni	RZP01	µg/l	0,088
Bentso(k)fluoranteeni	RZP01	µg/l	0,016
Bentso(a)pyreeni	RZP01	µg/l	0,031
Bentso(g,h,i)peryleeni	RZP01	µg/l	0,035
Dibentso(a,h)antraseeni	RZP01	µg/l	0,008
Fenantreeni	RZP01	µg/l	0,31
Fluoreeni	RZP01	µg/l	0,079
Fluoranteeni	RZP01	µg/l	0,23
Kryseeni	RZP01	µg/l	0,074
Indeno(1,2,3-cd)pyreeni	RZP01	µg/l	0,014
Naftaleeni	RZP01	µg/l	0,15
Pyreeni	RZP01	µg/l	0,22

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Näytenumero **750-2019-00035334**

Näytteen nimi 6. Märkä liete

Näytteen kuvaus Puhdistamoliete

Näytteenottoaika 25.06.2019

Pyreeni	RZP01	µg/l	0,22
Perfluoratut yhdisteet (PFC)			
Perfluorobutaanihappo (PFBA)	RZPFC	µg/l	<0,050
Perfluoropentaanihappo (PFPeA)	RZPFC	µg/l	<0,005
Perfluoroheksaanihappo (PFHxA)	RZPFC	µg/l	<0,005
Perfluoroheptaanihappo (PFHpA)	RZPFC	µg/l	<0,005
Perfluoro-oktaanihappo (PFOA)	RZPFC	µg/l	0,0050
Perfluorinonaanihappo (PFNA)	RZPFC	µg/l	<0,005
Perfluorodekaanihappo (PFDA)	RZPFC	µg/l	<0,005
Perfluoroundekaanihappo (PFUnA)	RZPFC	µg/l	<0,005
Perfluorododekaanihappo (PFDoA)	RZPFC	µg/l	<0,005
Perfluorotridekaanihappo (PFTrDA)	RZPFC	µg/l	<0,005
Perfluorotetradekaanihappo (PFTA)	RZPFC	µg/l	<0,005
Perfluoroheksadekaanihappo (PFHxDA)	RZPFC	µg/l	<0,005
Perfluoro-oktaanidekaanihappo (PFODA)	RZPFC	µg/l	<0,005
Perfluorobutaanisulfonaatti (PFBS)	RZPFC	µg/l	<0,005
Perfluoropentaanisulfonaatti (PFPeS)	RZPFC	µg/l	<0,005
Perfluoroheksaanisulfonaatti (PFHxS)	RZPFC	µg/l	<0,005
Perfluoroheptaanisulfonaatti (PFHpS)	RZPFC	µg/l	<0,005
Perfluoro-oktaanisulfonaatti (PFOS)	RZPFC	µg/l	0,035
Perfluorononaanisulfonaatti (PFNS)	RZPFC	µg/l	<0,005
Perfluorodekaanisulfonaatti (PFDS)	RZPFC	µg/l	<0,005
Perfluorododekaanisulfonaatti (PFDoS)	RZPFC	µg/l	<0,005
1H,1H,2H,2H-Perfluorohexanesulfonaatti (4:2 FTS)	RZPFC	µg/l	<0,005
1H,1H,2H,2H-Perfluoro-oktaanisulfonaatti (6:2 FTS)	RZPFC	µg/l	0,013
1H,1H,2H,2H-Perfluorodekaanisulfonaatti (8:2 FTS)	RZPFC	µg/l	<0,005

Tämä tuloste korvaa aiemman, 19/07/2019 päivätyn tulosteen AR-19-RZ-021514-01/750-2019-00035329

Menetelmätiedot

Testikoodi	Parametrin nimi, CAS	Menetelmän mittausepävarmuus	Menetelmän määritysraja	Akkreditoitu	Menetelmä	Laboratorio
Kuiva-aine						
RZDRY	Kuiva-ainepitoisuus	5%(<30%) 1,5%(>30%)	3	Kyllä	SFS 3008; SFS-ISO 11465; SFS-EN 15934	RZ T039
Alkuaineet, kokonaispitoisuus, HCl/HNO3, ICP-MS						
RZ0EB	Arseeni (As), 7440-38-2	20%	0.005	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0EV	Boori (B), 7440-42-8	25%	0.03	Ei	SFS-EN ISO 17294-2	RZ
RZ0EH	Elohopea (Hg), 7439-97-6	15 % (>0,001 mg/l) ja 25 % (<0,001 mg/l)	0.0001	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0EJ	Kadmium (Cd), 7440-43-9	20%	0.0001	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0FJ	Kalium (K), 7440-09-7	30%	0.2	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0F1	Kalsium (Ca), 7440-70-2	20%	0.2	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0EK	Koboltti (Co), 7440-48-4	20%	0.0005	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0EF	Kromi (Cr), 7440-47-3	20%	0.003	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0F2	Kupari (Cu), 7440-50-8	20%	0.003	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0ED	Lyijy (Pb), 7439-92-1	20%	0.001	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0F4	Magnesium (Mg), 7439-95-4	20%	0.1	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0F5	Mangaani (Mn), 7439-96-5	20%	0.005	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0EM	Molybdeeni (Mo), 7439-98-7	20%	0.001	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0FL	Natrium (Na), 7440-23-5	22%	0.2	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0EN	Nikkeli (Ni), 7440-02-0	20%	0.003	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0ET	Rauta (Fe), 7439-89-6	20%	0.025	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0FN	Rikki (S), 63705-05-5	22%	0.5	Ei	SFS-EN ISO 17294-2	RZ
RZ0FB	Seleeni (Se), 7782-49-2	20%	0.001	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZ0FC	Sinkki (Zn), 7440-66-6	20%	0.005	Kyllä	SFS-EN ISO 17294-2	RZ T039
RZE17	Mikroaaltohajotus			Kyllä	SFS-EN ISO 15587-1	RZ T039
Alkuaineet, kiinteä matriisi, pitoisuus kuiva-ainetta kohti, ICP-MS						
RZE18	Mikroaaltohajotus			Ei	SFS-EN 16174	RZ
RZ0VE	Arseeni (As), 7440-38-2	25%	1	Kyllä	SFS-EN 16171	RZ T039
RZ0VW	Boori (B), 7440-42-8	30%	10	Ei	SFS-EN 16171	RZ
RZ0VL	Elohopea (Hg), 7439-97-6	25%	0.1	Kyllä	SFS-EN 16171	RZ T039
RZ0VM	Kadmium (Cd), 7440-43-9	25%	0.2	Kyllä	SFS-EN 16171	RZ T039
RZ0VZ	Kalium (K), 7440-09-7	25%	100	Ei	SFS-EN 16171	RZ
RZ0W0	Kalsium (Ca), 7440-70-2	25%	100	Ei	SFS-EN 16171	RZ
RZ0VN	Koboltti (Co), 7440-48-4	20%	1	Kyllä	SFS-EN 16171	RZ T039
RZ0VG	Kromi (Cr), 7440-47-3	25%	1	Kyllä	SFS-EN 16171	RZ T039

Alkuaineet, kiinteä matriisi, pitoisuus kuiva-ainetta kohti, ICP-MS						
RZ0VG	Kromi (Cr), 7440-47-3	25%	1	Kyllä	SFS-EN 16171	RZ T039
RZ0W1	Kupari (Cu), 7440-50-8	25%	5	Kyllä	SFS-EN 16171	RZ T039
RZ0VH	Lyijy (Pb), 7439-92-1	25%	1	Kyllä	SFS-EN 16171	RZ T039
RZ0W2	Magnesium (Mg), 7439-95-4	25%	100	Ei	SFS-EN 16171	RZ
RZ0W3	Mangaani (Mn), 7439-96-5	25%	5	Kyllä	SFS-EN 16171	RZ T039
RZ0VP	Molybdeeni (Mo), 7439-98-7	20%	2	Ei	SFS-EN 16171	RZ
RZ0W4	Natrium (Na), 7440-23-5	25%	100	Ei	SFS-EN 16171	RZ
RZ0VI	Nikkeli (Ni), 7440-02-0	25%	2	Kyllä	SFS-EN 16171	RZ T039
RZ0VT	Rauta (Fe), 7439-89-6	30%	10	Kyllä	SFS-EN 16171	RZ T039
RZ0W5	Rikki (S), 63705-05-5	25%	500	Ei	SFS-EN 16171	RZ
RZ0VQ	Seleeni (Se), 7782-49-2	25%	1	Kyllä	SFS-EN 16171	RZ T039
RZ0W6	Sinkki (Zn), 7440-66-6	25%	5	Kyllä	SFS-EN 16171	RZ T039
Lääkeaineet						
RZPDR	4-Asetamidoantipyrine, 83-15-8	42%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	4-Formyyliaminoantipyri ini, 1672-58-8	42%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	5-metyylibentsotriatsoli, 136-85-6	55%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Amiloridi, 2016-88-8	23%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Amiodaroni, 1951-25-3	53%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Amlodipiini, 88150-42-9	54%	0.2	Kyllä	EPA 1694	RZ T039
RZPDR	Amoksisilliini, 26787-78-0	44%	0.1	Kyllä	EPA 1694	RZ T039
RZPDR	Ampisilliini, 69-53-4	32%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Asetanilidi, 103-84-4	38%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Atenololi, 29122-68-7	37%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Atorvastatiini, 134523-00-5	44%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Atsatiopriini, 446-86-6	25%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Atsitromysiini, 83905-01-5	47%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Beklometasoni, 4419-39-0	51%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Bendroflumetiatsidi, 73-48-3	54%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Bentsotriatsoli, 95-14-7	45%	0.04	Kyllä	EPA 1694	RZ T039
RZPDR	Betsafibraatti, 41859-67-0	38%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Bisoprololi (ß-Adrenergics), 66722-44-9	52%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Bromokriptiini, 25614-03-3	48%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Budesonidi, 51333-22-3	24%	0.01	Kyllä	EPA 1694	RZ T039

Lääkeaineet

RZPDR	Budesonidi, 51333-22-3	24%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Buspironi, 36505-84-7	50%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Dapsoni, 80-08-0	42%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Desloratadiini, 100643-71-8	41%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Diatritsoaatti (Amidotritsoaatti), 117-96-4	42%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Diklofenaakki, 15307-86-5	46%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Doksisykliini, 564-25-0	51%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Enalapriili, 75847-73-3	40%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Enrofloksasiini, 93106-60-6	43%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Entakaponi, 130929-57-6	46%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Erytromysiini, 114-07-8	48%	0.25	Kyllä	EPA 1694	RZ T039
RZPDR	Febanteeli, 58306-30-2	49%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Felodipiini, 72509-76-3	55%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Fenatsoni, 60-80-0	34%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Fenbendatsoli, 43210-67-9	33%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Flubendatsoli, 31430-15-6	47%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Fluoksetiini, 54910-89-3	26%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Flutamidi, 13311-84-7	39%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Fluvastatiini, 93957-54-1	47%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Fluvoksamiini, 54739-18-3	48%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Furosemidi, 54-31-9	48%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Gemifibrotsiili, 25812-30-0	50%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Glyburidi (Glibenklamidi), 10238-21-8	42%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Hydroklooritiatsidi, 58-93-5	49%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Hydrokortisoni, 50-23-7	44%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Ibuprofeeni, 15687-27-1	44%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Ifosfamidi, 3778-73-2	36%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Iopamidoli, 60166-93-0	48%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Iopromidi, 73334-07-3	46%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Ipratropium, 60205-81-4	51%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Ivermektiini, 70288-86-7	52%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Karbamatsepiini, 298-46-4	40%	0.005	Kyllä	EPA 1694	RZ T039

Lääkeaineet

RZPDR	Karvediloli, 72956-09-3	55%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Ketiapiini, 111974-69-7	40%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Ketokonatsoli, 65277-42-1	43%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Ketoprofeeni, 22071-15-4	51%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Klaritromysiini, 81103-11-9	51%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Klenbuteroli, 37148-27-9	25%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Klofibrihappo, 882-09-7	55%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Kloksasilliini, 61-72-3	44%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Klotsapiini, 5786-21-0	28%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Kofeiini, 58-08-2	44%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Ksylometatsoliini, 526-36-3	43%	0.001	Kyllä	EPA 1694	RZ T039
RZPDR	Lamotrigiini, 84057-84-1	48%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Loratadiini, 79794-75-5	33%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Losartaani, 114798-26-4	48%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Meropeneemi, 119478-56-7	47%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Metoprololi, 37350-58-6	46%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Metotreksaatti, 59-05-2	39%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Metronidatsoli, 443-48-1	34%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Metyyliprednisoloni, 83-43-2	36%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Mianseriini, 24219-97-4	43%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Mirtatsapiini, 61337-67-5	43%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Mometasonifuroaatti, 83919-23-7	34%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	N4-Asetyylisulfametoksatsoli, 21312-10-7	42%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Naprokseeni, 22204-53-1	39%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	N-Demetyylierytromysiini A, 992-62-1	51%	0.2	Kyllä	EPA 1694	RZ T039
RZPDR	Nelfinaviiri, 159989-64-7	55%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Nitenpyram, 150824-47-8	44%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Norfloksasiini, 70458-96-7	41%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Ofloksasiini, 82419-36-1	44%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Oksitetrasykliini, 79-57-2	52%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Oksymetatsoli, 1491-59-4	51%	0.005	Kyllä	EPA 1694	RZ T039

Lääkeaineet

RZPDR	Parasetamoli, 103-90-2	47%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Paroksetiini, 61869-08-7	40%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Penisilliini G -bentsatiini, 1538-09-6	49%	0.5	Kyllä	EPA 1694	RZ T039
RZPDR	Piperasilliini, 66258-76-2	38%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Pratsikvanteli, 55268-74-1	48%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Primidoni, 125-33-7	41%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Propafenoni, 54063-53-5	42%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Propanololi, 525-66-6	45%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Propyfenatsoni, 479-92-5	42%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Pyranteeli, 15686-83-6	45%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Raloksifeeni, 84449-90-1	28%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Ramipriili, 87333-19-5	33%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Risperidoni, 106266-06-2	38%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Roksitromysiini, 80214-83-1	43%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Salbutamoli (albuteroli), 18559-94-9	55%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Salmeteroli, 89365-50-4	37%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Sertraliini ja norsertraliini	48%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Setiritsiini, 83881-51-0	45%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Simvastatiini, 79902-63-9	52%	0.5	Kyllä	EPA 1694	RZ T039
RZPDR	Siprofloksasiini, 85721-33-1	38%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Sitalopraami, 59729-33-8	50%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Sotaloli, 3930-20-9	46%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Sulfadiatsiini, 68-35-9	33%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Sulfadimidiini (Sulfametatsiini), 57-68-1	53%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Sulfadoksiini, 2447-57-6	46%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Sulfaguanidiini, 57-67-0	53%	0.05	Kyllä	EPA 1694	RZ T039
RZPDR	Sulfameratsiini, 127-79-7	45%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Sulfametitsoli, 144-82-1	53%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Sulfametoksatsoli, 723-46-6	54%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Sulfatiatsoli, 72-14-0	40%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Syklofosfamidi, 50-18-0	32%	0.005	Kyllä	EPA 1694	RZ T039

Lääkeaineet

RZPDR	Tamoksifeeni, 10540-29-1	49%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Terbutaliini, 23031-25-6	43%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Tetrasykliini, 60-54-8	46%	0.01	Kyllä	EPA 1694	RZ T039
RZPDR	Toremifeeni, 89778-26-7	49%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Tramadoli, 27203-92-5	51%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Triklokarbaani, 101-20-2	30%	0.04	Kyllä	EPA 1694	RZ T039
RZPDR	Trimetoprim, 738-70-5	45%	0.001	Kyllä	EPA 1694	RZ T039
RZPDR	Tylosiini, 1401-69-0	46%	0.02	Kyllä	EPA 1694	RZ T039
RZPDR	Varfariini, 81-81-2	40%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Venlafaksiini, 93413-69-5	51%	0.005	Kyllä	EPA 1694	RZ T039
RZPDR	Verapamiili, 52-53-9	36%	0.005	Kyllä	EPA 1694	RZ T039
RZ1T3	4-Asetamidoantipyrine, 83-15-8	42%	0.01	Kyllä	EPA 1694	RZ T039
RZ1TB	4-Formyyliaminoantipyrini, 1672-58-8	42%	0.02	Kyllä	EPA 1694	RZ T039
RZ1T4	5-metyylibentsotriatsoli, 136-85-6	55%	0.01	Kyllä	EPA 1694	RZ T039
RZ1S7	Amiloridi, 2016-88-8	23%	0.005	Kyllä	EPA 1694	RZ T039
RZ1TC	Amiodaroni, 1951-25-3	53%	0.02	Kyllä	EPA 1694	RZ T039
RZ1S4	Amlodipiini, 88150-42-9	54%	0.2	Kyllä	EPA 1694	RZ T039
RZ1TI	Amoksisilliini, 26787-78-0	44%	0.1	Kyllä	EPA 1694	RZ T039
RZ1RG	Ampisilliini, 69-53-4	32%	0.005	Kyllä	EPA 1694	RZ T039
RZ1T5	Asetanilidi, 103-84-4	38%	0.01	Kyllä	EPA 1694	RZ T039
RZ1QH	Atenololi, 29122-68-7	37%	0.005	Kyllä	EPA 1694	RZ T039
RZ1RY	Atorvastatiini, 134523-00-5	44%	0.01	Kyllä	EPA 1694	RZ T039
RZ1S8	Atsatiopriini, 446-86-6	25%	0.005	Kyllä	EPA 1694	RZ T039
RZ1T6	Atsitromysiini, 83905-01-5	47%	0.01	Kyllä	EPA 1694	RZ T039
RZ1QI	Beklometasoni, 4419-39-0	51%	0.005	Kyllä	EPA 1694	RZ T039
RZ1RZ	Bendroflumetiatsidi, 73-48-3	54%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RE	Bentsotriatsoli, 95-14-7	45%	0.04	Kyllä	EPA 1694	RZ T039
RZ1Q4	Betsafibraatti, 41859-67-0	38%	0.005	Kyllä	EPA 1694	RZ T039
RZ1QY	Bisoprololi (ß-Adrenergics), 66722-44-9	52%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RN	Bromokriptiini, 25614-03-3	48%	0.005	Kyllä	EPA 1694	RZ T039
RZ1S0	Budesonidi, 51333-22-3	24%	0.01	Kyllä	EPA 1694	RZ T039
RZ1S9	Buspironi, 36505-84-7	50%	0.005	Kyllä	EPA 1694	RZ T039
RZ1RH	Dapsoni, 80-08-0	42%	0.01	Kyllä	EPA 1694	RZ T039

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RZ1RP	Desloratadiini, 100643-71-8	41%	0.005	Kyllä	EPA 1694	RZ T039
RZ1TD	Diatritsoaatti (Amidotritsoaatti), 117-96-4	42%	0.02	Kyllä	EPA 1694	RZ T039
RZ1Q5	Diklofenaakki, 15307-86-5	46%	0.005	Kyllä	EPA 1694	RZ T039
RZ1PZ	Doksisykliini, 564-25-0	51%	0.02	Kyllä	EPA 1694	RZ T039
RZ1QL	Enalapriili, 75847-73-3	40%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RK	Enrofloksasiini, 93106-60-6	43%	0.02	Kyllä	EPA 1694	RZ T039
RZ1QZ	Entakaponi, 130929-57-6	46%	0.01	Kyllä	EPA 1694	RZ T039
RZ1S5	Erytromysiini, 114-07-8	48%	0.25	Kyllä	EPA 1694	RZ T039
RZ1SA	Febanteeli, 58306-30-2	49%	0.005	Kyllä	EPA 1694	RZ T039
RZ1RQ	Fenatsoni, 60-80-0	34%	0.005	Kyllä	EPA 1694	RZ T039
RZ1QU	Fenbendatsoli, 43210-67-9	33%	0.005	Kyllä	EPA 1694	RZ T039
RZ1QV	Flubendatsoli, 31430-15-6	47%	0.005	Kyllä	EPA 1694	RZ T039
RZ1QM	Fluoksetiini, 54910-89-3	26%	0.01	Kyllä	EPA 1694	RZ T039
RZ1SB	Flutamidi, 13311-84-7	39%	0.005	Kyllä	EPA 1694	RZ T039
RZ1T7	Fluvastatiini, 93957-54-1	47%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RR	Fluvoksamiini, 54739-18-3	48%	0.005	Kyllä	EPA 1694	RZ T039
RZ1S3	Furosemidi, 54-31-9	48%	0.05	Kyllä	EPA 1694	RZ T039
RZ1QN	Gemifibrotsiili, 25812-30-0	50%	0.01	Kyllä	EPA 1694	RZ T039
RZ1S1	Glyburidi (Glibenklamidi), 10238-21-8	42%	0.01	Kyllä	EPA 1694	RZ T039
RZ1QS	Hydroklooritiatsidi, 58-93-5	49%	0.05	Kyllä	EPA 1694	RZ T039
RZ1QP	Hydrokortisoni, 50-23-7	44%	0.01	Kyllä	EPA 1694	RZ T039
RZ1QE	Ibuprofeeni, 15687-27-1	44%	0.05	Kyllä	EPA 1694	RZ T039
RZ1R3	Iopamidoli, 60166-93-0	48%	0.02	Kyllä	EPA 1694	RZ T039
RZ1R4	Iopromidi, 73334-07-3	46%	0.02	Kyllä	EPA 1694	RZ T039
RZ1SC	Ipratropium, 60205-81-4	51%	0.005	Kyllä	EPA 1694	RZ T039
RZ1Q8	Ivermektiini, 70288-86-7	52%	0.01	Kyllä	EPA 1694	RZ T039
RZ1Q6	Karbamatsepiini, 298-46-4	40%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SD	Karvediloli, 72956-09-3	55%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SE	Ketiapiini, 111974-69-7	40%	0.005	Kyllä	EPA 1694	RZ T039
RZ1RS	Ketokonatsoli, 65277-42-1	43%	0.005	Kyllä	EPA 1694	RZ T039
RZ1Q7	Ketoprofeeni, 22071-15-4	51%	0.005	Kyllä	EPA 1694	RZ T039

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RZ1R7	Klaritromysiini, 81103-11-9	51%	0.01	Kyllä	EPA 1694	RZ T039
RZ1PY	Klenbuteroli, 37148-27-9	25%	0.005	Kyllä	EPA 1694	RZ T039
RZ1QF	Klofibrihappo, 882-09-7	55%	0.05	Kyllä	EPA 1694	RZ T039
RZ1R9	Kloksasilliini, 61-72-3	44%	0.005	Kyllä	EPA 1694	RZ T039
RZ1RT	Klotsapiini, 5786-21-0	28%	0.005	Kyllä	EPA 1694	RZ T039
RZ1Q1	Kofeiini, 58-08-2	44%	0.01	Kyllä	EPA 1694	RZ T039
RZ1S6	Ksylometatsoliini, 526-36-3	43%	0.001	Kyllä	EPA 1694	RZ T039
RZ1SF	Lamotrigiini, 84057-84-1	48%	0.005	Kyllä	EPA 1694	RZ T039
RZ1RU	Loratadiini, 79794-75-5	33%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SG	Losartaani, 114798-26-4	48%	0.005	Kyllä	EPA 1694	RZ T039
RZ1TH	Meropeneemi, 119478-56-7	47%	0.05	Kyllä	EPA 1694	RZ T039
RZ1QW	Metoprololi, 37350-58-6	46%	0.005	Kyllä	EPA 1694	RZ T039
RZ1R0	Metotreksaatti, 59-05-2	39%	0.01	Kyllä	EPA 1694	RZ T039
RZ1R5	Metronidatsoli, 443-48-1	34%	0.02	Kyllä	EPA 1694	RZ T039
RZ1R1	Metyyliprednisoloni, 83-43-2	36%	0.01	Kyllä	EPA 1694	RZ T039
RZ1SH	Mianseriini, 24219-97-4	43%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SI	Mirtatsapiini, 61337-67-5	43%	0.005	Kyllä	EPA 1694	RZ T039
RZ1TE	Mometasonifuroaatti, 83919-23-7	34%	0.02	Kyllä	EPA 1694	RZ T039
RZ1SJ	N4-Asetyylisulfametoksatsoli, 21312-10-7	42%	0.005	Kyllä	EPA 1694	RZ T039
RZ1Q9	Naprokseeni, 22204-53-1	39%	0.01	Kyllä	EPA 1694	RZ T039
RZ1TJ	N-Demetyylierytromysiini A, 992-62-1	51%	0.2	Kyllä	EPA 1694	RZ T039
RZ1SK	Nelfinaviiri, 159989-64-7	55%	0.005	Kyllä	EPA 1694	RZ T039
RZ1T8	Nitenpyram, 150824-47-8	44%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RL	Norfloksasiini, 70458-96-7	41%	0.05	Kyllä	EPA 1694	RZ T039
RZ1RF	Ofloksasiini, 82419-36-1	44%	0.05	Kyllä	EPA 1694	RZ T039
RZ1SL	Oksymetatsoli, 1491-59-4	51%	0.005	Kyllä	EPA 1694	RZ T039
RZ1QG	Oksitetrasykliini, 79-57-2	52%	0.05	Kyllä	EPA 1694	RZ T039
RZ1TF	Parasetamoli, 103-90-2	47%	0.02	Kyllä	EPA 1694	RZ T039
RZ1QJ	Paroksetiini, 61869-08-7	40%	0.005	Kyllä	EPA 1694	RZ T039
RZ1TK	Penisilliini G -bentsatiini, 1538-09-6	49%	0.5	Kyllä	EPA 1694	RZ T039
RZ1T9	Piperasilliini, 66258-76-2	38%	0.01	Kyllä	EPA 1694	RZ T039

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RZ1T9	Piperasilliini, 66258-76-2	38%	0.01	Kyllä	EPA 1694	RZ T039
RZ1SM	Pratsikvanteli, 55268-74-1	48%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SN	Primidoni, 125-33-7	41%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SP	Propafenoni, 54063-53-5	42%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SQ	Propanololi, 525-66-6	45%	0.005	Kyllä	EPA 1694	RZ T039
RZ1RV	Propyfenatsoni, 479-92-5	42%	0.005	Kyllä	EPA 1694	RZ T039
RZ1TA	Pyranteeli, 15686-83-6	45%	0.01	Kyllä	EPA 1694	RZ T039
RZ1SS	Raloksifeeni, 84449-90-1	28%	0.005	Kyllä	EPA 1694	RZ T039
RZ1ST	Ramipriili, 87333-19-5	33%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SU	Risperidoni, 106266-06-2	38%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SV	Roksitromysiini, 80214-83-1	43%	0.005	Kyllä	EPA 1694	RZ T039
RZ1QA	Salbutamoli (albuteroli), 18559-94-9	55%	0.01	Kyllä	EPA 1694	RZ T039
RZ1SW	Salmeteroli, 89365-50-4	37%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SR	Sertraliini ja norsertraliini	48%	0.005	Kyllä	EPA 1694	RZ T039
RZ1RW	Setiritsiini, 83881-51-0	45%	0.005	Kyllä	EPA 1694	RZ T039
RZ1QT	Simvastatiini, 79902-63-9	52%	0.5	Kyllä	EPA 1694	RZ T039
RZ1RM	Siprofloksasiini, 85721-33-1	38%	0.05	Kyllä	EPA 1694	RZ T039
RZ1QQ	Sitalopraami, 59729-33-8	50%	0.01	Kyllä	EPA 1694	RZ T039
RZ1R2	Sotaloli, 3930-20-9	46%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RA	Sulfadiatsiini, 68-35-9	33%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RI	Sulfadimidiini (Sulfametatsiini), 57-68-1	53%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RB	Sulfadoksiini, 2447-57-6	46%	0.01	Kyllä	EPA 1694	RZ T039
RZ1R8	Sulfaguanidiini, 57-67-0	53%	0.05	Kyllä	EPA 1694	RZ T039
RZ1RC	Sulfameratsiini, 127-79-7	45%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RJ	Sulfametitsoli, 144-82-1	53%	0.01	Kyllä	EPA 1694	RZ T039
RZ1QB	Sulfametoksatsoli, 723-46-6	54%	0.01	Kyllä	EPA 1694	RZ T039
RZ1RD	Sulfatiatsoli, 72-14-0	40%	0.01	Kyllä	EPA 1694	RZ T039
RZ1QK	Syklofosfamidi, 50-18-0	32%	0.005	Kyllä	EPA 1694	RZ T039
RZ1SY	Tamoksifeeni, 10540-29-1	49%	0.005	Kyllä	EPA 1694	RZ T039
RZ1Q2	Terbutaliini, 23031-25-6	43%	0.01	Kyllä	EPA 1694	RZ T039
RZ1QC	Tetrasykliini, 60-54-8	46%	0.01	Kyllä	EPA 1694	RZ T039
RZ1SZ	Toremifeeni, 89778-26-7	49%	0.005	Kyllä	EPA 1694	RZ T039

Lääkeaineet						
RZ1SZ	Toremifeeni, 89778-26-7	49%	0.005	Kyllä	EPA 1694	RZ T039
RZ1T0	Tramadoli, 27203-92-5	51%	0.005	Kyllä	EPA 1694	RZ T039
RZ1TG	Triklokarbaani, 101-20-2	30%	0.04	Kyllä	EPA 1694	RZ T039
RZ1Q3	Trimetoprim, 738-70-5	45%	0.001	Kyllä	EPA 1694	RZ T039
RZ1Q0	Varfariini, 81-81-2	40%	0.005	Kyllä	EPA 1694	RZ T039
RZ1T1	Venlafaksiini, 93413-69-5	51%	0.005	Kyllä	EPA 1694	RZ T039
RZ1T2	Verapamiili, 52-53-9	36%	0.005	Kyllä	EPA 1694	RZ T039
PAH EPA 16 yhdisteet						
RZP01	Asenafteeni, 83-32-9	22%	0.005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Asenaftyleeni, 208-96-8	25%	0.005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Antraseeni, 120-12-7	18%	0.005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Bentso(a)antraseeni, 56-55-3	28%	0.001	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Bentso(b/j)fluoranteeni, 205-82-3 / 205-82-3	25%	0.001	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Bentso(k)fluoranteeni, 207-08-9	27%	0.001	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Bentso(a)pyreeni, 50-32-8	26%	0.00017	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Bentso(g,h,i)peryleeni, 191-24-2	17%	0.0005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Dibentso(a,h)antraseeni , 53-70-3	23%	0.0005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Fenantreeni, 85-01-8	20%	0.005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Fluoreeni, 86-73-7	22%	0.005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Fluoranteeni, 206-44-0	23%	0.005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Kryseeni, 218-01-9	20%	0.001	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Indeno(1,2,3-cd)pyreeni , 193-39-5	17%	0.0005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Naftaleeni, 91-20-3	22%	0.01	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
RZP01	Pyreeni, 129-00-0	20%	0.005	Kyllä	ISO 28540, ISO/TS 28581	RZ T039
Perfluoratut yhdisteet (PFC)						
RZPFC	Perfluorobutaanihappo (PFBA), 375-22-4	28%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoropentaanihappo (PFPeA), 2706-90-3	21%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoroheksaanihapp o (PFHxA), 307-24-4	20%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoroheptaanihappo (PFHpA), 375-85-9	21%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoro-oktaanihappo (PFOA), 335-67-1	22%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluorinonaanihappo (PFNA), 375-95-1	27%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluorodekaanihappo (PFDA), 335-76-2	26%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039

Perfluoratut yhdisteet (PFC)						
RZPFC	Perfluoroundekaanihappo (PFUnA), 2058-94-8	30%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluorododekaanihappo (PFDoA), 307-55-1	29%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluorotridekaanihappo (PFTrDA), 72629-94-8	40%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluorotetradekaanihappo (PFTA), 376-06-7	40%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoroheksadekaanihappo (PFHxDA), 67905-19-5	40%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoro-oktaanidekaanihappo (PFODA), 16517-11-6	40%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluorobutaanisulfonaatti (PFBS), 375-73-5	23%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoropentaanisulfonaatti (PFPeS), 2706-91-4	40%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoroheksaanisulfonaatti (PFHxS), 355-46-4	21%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoroheptaanisulfonaatti (PFHpS), 375-92-8	27%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluoro-oktaanisulfonaatti (PFOS), 1763-23-1	24%	0.0001	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluorononaanisulfonaatti (PFNS), 68259-12-1	40%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluorodekaanisulfonaatti (PFDS), 335-77-3	36%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	Perfluorododekaanisulfonaatti (PFDoS), 79780-39-5	40%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	1H,1H,2H,2H-Perfluorohexanesulfonaatti (4:2 FTS), 757124-72-4	31%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	1H,1H,2H,2H-Perfluoro-oktaanisulfonaatti (6:2 FTS), 27619-97-2	31%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039
RZPFC	1H,1H,2H,2H-Perfluorodekaanisulfonaatti (8:2 FTS), 39108-34-4	37%	0.0005	Kyllä	Sis. men. EF 4041 , LC-MS/MS	RZ T039

Laboratorio		
RZ	Eurofins Environment Testing Finland (Lahti)	(Ei akkreditoitu)
RZ T039	Eurofins Environment Testing Finland (Lahti)	FINAS akkr. num. SFS-EN ISO/IEC 17025:2017 FINAS T039

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ALLEKIRJOITUS

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Tutkimustodistus on sähköisesti hyväksytty.

Lisätietoja

Analysoidut yhdisteet on esitetty todistuksessa seuraavasti:
- jos analysoitua yhdistettä ei havaita, analysoidun yhdisteen kohdalla esitetään määritysraja ko. näytteelle
- jos tulos on yli toteamisrajan mutta alle määritysrajan, merkitään tuloksen perään tähti (*)
- jos tulos on yli määritysrajan, tulos on esitetty yhdisteen kohdalla
- menetelmäosiossa on esitetty määritysrajat optimiolosuhteissa. Määritysrajat saattavat olla korkeammat näytematriisista johtuen.

Korvaavan syy: Lisätty PFC tulokset.

Huomautukset

Tutkimustodistuksen osittainen julkaiseminen on sallittu vain laboratorion kirjallisella luvalla. Testaustulokset koskevat vain vastaanotettua ja tutkittua näytettä. Mahdollinen lausunto ei kuulu akkreditoinnin piiriin.